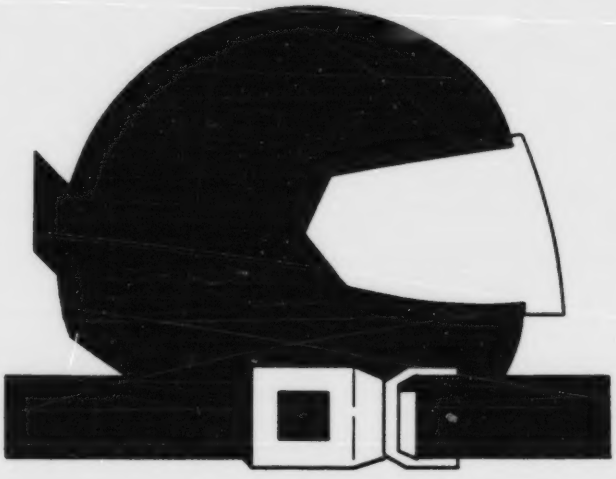
THE IMPACT OF BILL 60;

A STUDY TO EVALUATE THE EFFECTIVENESS OF MANDATORY SEAT BELT AND MOTORCYCLE HELMET USE LEGISLATION IN MANITOBA



THE UNIVERSITY OF MANITOBA

ROAD SAFETY RESEARCH UNIT

THE IMPACT OF BILL 60;

A STUDY TO EVALUATE THE EFFECTIVENESS OF MANDATORY SEAT BELT AND MOTORCYCLE HELMET USE LEGISLATION IN MANITOBA

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VOLUME I

TECHNICAL REPORT

THE UNIVERSITY OF MANITOBA

ROAD SAFETY RESEARCH UNIT

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PREAMBLE

This study was commissioned by the Government of Canada, Transport Canada; and the Province of Manitoba, Highways and Transportation, under the Canada-Manitoba Subsidiary Agreement on Transportation. The object of the study as stated in the Terms of Reference, was:

> to carry out an evaluation of the effectiveness of Manitoba's legislation requiring the use of seat belts by vehicle occupants and helmets by motorcyclists.

Although this legislation was enacted on January 1, 1984, a three month grace period was provided before enforcement began on April 1, 1984.

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PART A: THE IMPACT OF MANDATORY SEAT BELT USE LEGISLATION

1) INTRODUCTION

1.1) EFFECTIVENESS OF THREE POINT RESTRAINT SYSTEMS

Although the effectiveness of seat belts in reducing the severity of injuries sustained in motor vehicle collisions has been extensively documented in the scientific literature, numerous efforts are still being made to quantify these benefits, especially in terms of establishing the effectiveness of mandatory use legislation. Methods used have recently been described by Hedlund (1) in terms of statistical studies, clinical studies and matched comparisons.

o Statistical Studies - Statistical studies using large collision data bases have compared the incidence and severity of injuries sustained by unrestrained motor vehicle occupants to injuries sustained by restrained occupants. Unfortunately, many confounding variables make this comparison difficult. For instance, it has been shown that restrained drivers are different than those who are unrestrained; they tend to drive differently and become involved in dissimilar types of collisions (2). Studies which do not take the fundamental differences between users and nonusers of seat belts into account often completely misrepresent the effectiveness of seat belts.

The most recent effort to synthesize the available knowledge of occupant restraint effectiveness based on the analysis of collision data bases, was presented by the National Highway Traffic Safety Administration in their Final Regulatory Impact Analysis of amendments to Federal Motor Vehicle Safety Standard 208 (3). NHTSA used three data bases describing collisions which occurred in the United States to form the basis of this analysis. After controlling for numerous collision related factors, including the severity of collisions, NHTSA concluded that over the entire population of fatal collisions the effectiveness of three point restraint systems was between 40 and 50%. That is, in a collision of given severity, a restrained occupant would be 40-50% less likely to be fatally injured than an unrestrained occupant.

A second innovative approach to analysing collision data bases, recently developed by Evans (4), used the FARS (Fatal Accident Reporting System) data base to conclude that the effectiveness of three point seat belts in fatal collisions was 41 $\pm$ 4% (5). The method developed by Evans, the double-pair comparison, has rapidly become an internationally recognized method to assess the effectiveness of safety systems and eliminate most of the confounding biases which have plagued prior analyses. The double-pair analysis does assume, however, that all occupants presently unbelted would use the available seat belt without changing their driving behavior.

Statistical estimates of seat belt effectiveness have also been determined by examining changes in the numbers of injuries or fatalities occurring in a jurisdiction which introduces mandatory use legislation. In this analysis, the number of injuries or fatalities in the post-legislation environment is compared with the expected number of injuries or fatalities

which would have occurred had the legislation not been introduced. An important aspect of this type of analysis is the prediction of the number of collisions or casualties expected to occur in the study area. To establish a trend a number of methods have been used and accepted by the scientific community.

First, the number of fatalities occurring over a specific time period in a jurisdiction without seat belt legislation was used to estimate the number of fatalities in another where the legislation was introduced (6). The first region represents the control group (no legislation is introduced) while the effectiveness of the legislation in the second area is evaluated. Similarly, if a seat belt use law is applied to one area of the road network and not to another (rural roads vs urban roads) then changes in fatality rates in each of the two areas can be compared to obtain an estimate of effectiveness (7). Such methods of estimating the expected number of fatalities assumes that the multitude of factors affecting the incidence of the collisions being evaluated is the same and constant over time between each geographical area.

Second, a trend has been established by identifying changes in the numbers of other road user casualties who are <u>not</u> affected by the legislation (bicyclists, motorcyclists or pedestrians). Utilizing these as a control, it is assumed that persons required to wear seat belts will do so and not change their driving behavior. It is further assumed that the causal variables affecting the incidence and severity of collisions within each category of road user are the same and constant over time.

Finally, fatality trends have been established by conducting a time series analysis of collision data to identify any change in the frequencies of events prior to and following the introduction of legislation. Where sufficient data has not been obtained, a simplistic before/after study may be conducted. This type of study is most susceptible to random yearly variations in the number of collisions or injuries.

The only direct method of estimating the effectiveness of a seat belt use laws is by statistical analysis. Effectiveness is determined by comparing the changes in injuries with the changes in seat belt use rates, while attempting to control for random changes or trends which may be influenced by other factors such as reporting methods. This relationship has been presented as follows (1);

$$\text{Belt law performance } (p) = \frac{\left[1 - \frac{C2}{C1}\right] + (t) - 1}{(t)[V2 - V1] + V1\left[1 - \frac{C2}{C1}\right]}$$

where C1 = casualties before
C2 = casualties after
V1 = usage before
V2 = usage after
t = trend factor estimating expected number of casualties

Note: $[1 - \frac{C2}{C1}]$ is the proportionate casualty reduction while if $t<1$ the number of casualties would be expected to drop without the law and if $t>1$ the number of fatalities would be expected to increase without the law.

The most recent estimates of seat belt performance and effectiveness of mandatory seat belt use legislation has been made through statistical analysis of mandatory use legislation in the United States. By June, 1986, seventeen states and the District of Columbia had introduced mandatory seat belt use legislation. To evaluate the effectiveness of the legislation, a number of studies were conducted utilizing the FARS data base, which documents all motor vehicle collisions involving a fatally injured person. Although the same data was used in several studies, estimates of seat belt effectiveness differ because of varying methods used to predict the expected number of fatalities.

Lund (8) examined the fatality trend in four states with mandatory use legislation; New York, Michigan, New Jersey and Illinois. To establish a trend each state with mandatory use legislation was compared to several control states (states with similar geographic characteristics) and then both a regression analysis and time series analysis were conducted. While it was concluded that all states experienced a decrease in the number of fatalities due to mandatory use legislation, only the decrease estimated for the State of New York (-16%) was statistically significant. Estimates of seat belt effectiveness for Michigan, New Jersey and Illinois were 10, 6 and 5% respectively and were not statistically significant.

Partyka (9,10) used several techniques to determine the expected number of fatalities including a simple before/after comparison of 1983 and then 1984 data, using all states without legislation as a control, and using other nonoccupant fatalities (motorcyclists, bicyclists, pedestrians) to estimate a trend. She suggested that mandatory use legislation had reduced the number of fatalities in 1985 by 7% and by 11% during the first half of 1986. Hoxie (11) utilized two time series analyses based on state and national models predicting motor vehicle occupant fatalities. His study concluded that the overall effect of legislation was to reduce the number of fatalities by approximately 6%. It was interesting to note, using this method, that in one state the legislation was shown to <u>increase</u> the number of fatalities by 18%.

Although it is recognized that mandatory use legislation should have a significant effect on the incidence and severity of injuries sustained by motor vehicle occupants, relatively little has been done to estimate the effects of legislation on the incidence and severity of injuries. This is because appropriate and reliable data bases generally do not exist. In one study, States (12) attempted to quantify the effect of legislation on the incidence, distribution and severity of hospital admissions in New York. A preliminary analysis showed that the number of hospital admissions had declined by approximately 18%. To establish a trend in this study, the incidence and severity of nonoccupant injuries (pedestrians, motorcyclists and bicyclists) was used.

In addition to experience in the United States, recent studies have been conducted, in the United Kingdom, to assess the impact of seat belt legislation introduced in January, 1983. Based on simple time series analysis, Mackay (13) concluded that the introduction of mandatory use legislation reduced the number of fatal and serious injuries by approximately 25%. Mackay also suggested that this reduction occurred without any discernable changes in the number of nonoccupant fatalities and serious injuries.

In addition, a more comprehensive study was undertaken by Rutherford (14) to establish the effect of legislation on the frequency, severity and distribution of injuries to motor vehicle occupants admitted to 14 different hospitals over a two year period; one year before and one year after the introduction of mandatory use legislation. It was concluded that there was a significant reduction in the number of patients, bed days, severe injuries to a single occupant, brain injuries and severe injuries to the face.

o Clinical Estimates - In measuring seat belt effectiveness by clinical estimates, individual collisions are reviewed by persons experienced in collision reconstruction, and the principles of injury causation and injury tolerance. For each collision the effectiveness of seat belts is measured by estimating the probable severity of injuries an unrestrained occupant would have received had restraints been used. Similarly, for those collisions involving persons who were restrained, an assessment of actual seat belt performance is made. This assessment of performance usually indicates whether 1) the use of a seat belt was effective in reducing the severity of injuries sustained by the occupant, 2) had no effect on the severity of injuries expected, or 3) caused injuries which were more severe than the injuries which would have been expected had the occupant been unrestrained.

This method has been criticized because it is based on the subjective judgement of those individuals conducting the evaluation, and because it may over-estimate the effectiveness of the restraint system by assuming that a seat belt if used, would have been worn properly. The method does not lead to a direct estimate of the effectiveness of seat belt use legislation but rather indicates a measure of the effectiveness or potential effectiveness of seat belt use in a sample of collisions. However, it is free from the confounding variables and systematic bias which makes statistical analysis of seat belt effectiveness and the evaluation of seat belt use legislation difficult.

Estimates of seat belt effectiveness based on clinical evaluations have been reported by Wilson (15), Griffiths (16) and Huelke (17). Effectiveness estimates in the samples of cases studied were determined to be 31%, 41% and 31-32% respectively. The differences in estimates can probably be attributed to the characteristics of the collisions which are used to produce the estimate. Data sets which involve a larger proportion of car vs large truck collisions, or other collisions in which measures of collision severity (eg. delta V) are greater, can be expected to yield a lower estimate of seat belt effectiveness.

o Matched Comparisons - A second method which uses actual field investigations to estimate the effectiveness of restraint systems has been described as the matching case methodology (18). Using this technique, collisions in which a specific type of restraint is used are compared to those collisions which involve similar injury producing potential but in which the occupants did not use the restraint system being evaluated. Collisions of similar injury producing potential are identified by examining the direction of force applied to the vehicle, area of vehicle damaged, type of damage, residual amount of vehicle crush, degree of intrusion into the occupant compartment, and a measure of collision severity (delta V or barrier equivalent velocity).

To conduct this type of investigation a large data base is required in order to match criteria cases with similar collisions involving equivalent injury producing potential. Estimates of collisions having equal injury producing potential is still somewhat subjective, although less so than the simple clinical approach.

1.2) THE EFFECTIVENESS OF TWO POINT LAP BELTS

The effectiveness of rear seat lap belts in providing adequate occupant protection has recently been questioned, in part, by a study based on the investigation of 26 frontal collisions (19). The study concluded that persons using only lap belts may not be adequately protected against injury and may sustain injuries induced by the lap belt itself which would be more severe than the injuries sustained had the occupant been unrestrained. This study has been criticized not only because of the limited number of cases from which the conclusions were drawn, but also because of an apparent bias in the case selection process. Not only was the severity of collisions (in terms of injury producing potential) greater than the severity of those which would have been expected, the resultant injuries were also greater in severity than those which would have been expected.

The controversy surrounding this issue led to a recent re-evaluation of lap belt effectiveness and the presentation of results at a recent scientific conference (20). At this time, estimates of rear seat lap belt performance was estimated utilizing both collision data bases and clinical studies.

Using the double-pair comparison, Evans (21, 22) estimated that, overall, the use of a lap belt reduces the probability of a rear seat occupant sustaining a fatal injury by 18 $\pm$ 9%. In frontal collisions only, it was estimated that the lap belt fatality reduction effect (-9 $\pm$ 17%) is less than the effectiveness in non-frontal collisions.

A similar analysis by Kahane (23) of the FARS data using the double-pair comparison technique, indicated that lap belts were 17-26% effective in reducing the risk of rear seat occupant fatalities. The double-pair analysis technique, also applied to a state accident data base, indicated the use of a rear seat lap belt reduces the risk of sustaining a serious injury by 37%, moderate to serious injuries by 33% and all injuries by 11% relative to an unrestrained occupant. It was concluded that in frontal crashes unrestrained rear seat occupants have approximately the same fatality risk as do restrained occupants, but in non-frontal collisions lap belted occupants are substantially safer (43%) than unrestrained occupants.

In addition, it was suggested that in frontal crashes, lap belted and unrestrained occupants are approximately as safe as the driver wearing a three point restraint system. This observation was supported by the results of clinical in-depth collision investigations by Huelke (24).

In a conventional analysis of police accident reported data in North Carolina, Campbell (25) concluded that the risk of a rear seat occupant sustaining serious or fatal injuries is reduced by 25-30% if the occupants are restrained. Partyka (26) attempted to utilize the NCSS-NASS data bases to estimate rear seat lap belt effectiveness but found that limited sample sizes precluded exhaustive analysis. Approximate estimates of effectiveness in reducing fatalities were suggested to be 39% and the effectiveness in reducing injury, 23%.

In Canada, Dalmotos (27) utilized the TRAID collision file and concluded that the use of lap belts reduces the probability of death by 20-30% in the case of rear seat adults, and by 40-50% in the case of children seated in the rear seat. This study attempted to adjust for expected inaccuracies in the reporting of seat belt use rates and used estimates of effectiveness in various collision configurations to control for the severity of collisions. It was also concluded that unlike three point front seat restraint systems, lap belts are more effective in non-frontal collisions compared to frontal collisions.

1.3) STUDY DESIGN - MANITOBA SEAT BELT EFFECTIVENESS STUDY

The original study design proposed numerous methodologies which could have been used to evaluate the impact of seat belt use legislation in Manitoba. However, a number of methods proved to be impossible or impractical to complete. For example it was proposed that the incidence and severity of injuries sustained in a sample of light truck and van (LTV) personal injury collisions investigated by the University of Manitoba Road Safety Research Unit (RSRU) prior to the introduction of legislation be compared with the distribution of injuries sustained in a similar sample of collisions occurring during two years following the introduction of legislation.

While this subset contained a relatively small number of incidents, the quality of data was such that a detailed analysis of injuries comparing restraint use while controlling for the severity of collisions and other collision related variables would have been possible.

This method was rejected after much of the data collection phase of the post-legislation subset was completed because it was discovered that the collisions investigated in the pre-legislation time period were biased in favor of those of greater severity. However, considerable use was made of the 117 cases which made up the post-legislation LTV file. Sixty-two of these cases were transferred to the fatality subset which was used in the clinical estimate study of seat belt effectiveness (item 4.2). In addition, many cases in which there were injured survivors were carefully analysed and matched to cases in the fatal file in which the potential for injury was judged to be equal. Hence, the nonfatal injury LTV file provided an additional objective dimension to a method which was, in many respects, a subjective exercise.

Analysis based on the Manitoba Public Insurance Corporation records was also investigated and then rejected because of difficulties in merging several data sets and the inability to retrieve the required information electronically. It was recognized that a significant amount of collision, injury, and cost data is available from the public insurance system, however, given the present structure of the system, an adequate analysis was beyond the resources allocated to this study.

The final design accepted was not necessarily the most efficient means of completing a very complex task. Of course, the general objective was to identify changes in injury trends attributable to seat belt use in Manitoba. However, in the investigation of fatal motor vehicle collisions, it went far beyond the simple task of comparing the actual number of injuries with the number which might have been expected. In fact, it was unique in that it took account of pre-crash and post-crash data regarding a wide range of human, vehicle, and environmental factors. These factors concerned collision and injury causation, and injury management, which, in time, could be useful in the development of future countermeasures.

2) EFFECTS ON SEAT BELT USAGE

2.1) SEAT BELT USE RATES IN MANITOBA

Estimates of seat belt usage in the general motoring population have been made by Transport Canada since 1979. These estimates, based on observational surveys, are used to document national and provincial belt use rates and to evaluate the effectiveness of several road safety initiatives. The surveys use a stratified multi-stage probability sample design to estimate use rates. In addition to these national surveys, similar surveys were performed on behalf of the Manitoba Traffic Safety Committee immediately before and shortly after the introduction of mandatory use legislation in Manitoba.

To provide an intermediate measure of seat belt use between the national surveys conducted in November 1984 and November 1985, a survey was conducted by the RSRU in June 1985 in accordance with this evaluation study. The survey was designed to replicate the national surveys conducted by Transport Canada. During this survey, seat belt use or nonuse was determined for 7,002 drivers, 5,125 of whom were drivers of passenger cars while 1,877 were drivers of light trucks or vans.

In the spring of 1986, a Selective Traffic Enforcement Program (STEP), was conducted to increase seat belt use rates throughout the province. As part of this program, three surveys of seat belt use were conducted. Although the site sampling criteria differed slightly it was assumed that the surveys conducted by the RSRU, for the Safety Committee, and the STEP surveys, were comparable to surveys conducted by Transport Canada.

The results of observational seat belt surveys conducted in Manitoba from November 1979 to November 1986 are presented in Table 2.1.

Date	Description of Survey	% of Drivers Wearing Shoulder Belts in Cars Equipped with Shoulder Belt
Nov. 1979	Transport Canada Annual Survey	6%
Nov. 1980	Transport Canada Annual Survey	6%
Nov. 1981	Transport Canada Annual Survey	6%
Nov. 1982	Transport Canada Annual Survey	7%
Nov. 1983	Transport Canada Annual Survey	11%
Feb. 1984	Survey conducted for Traffic Safety Committee	34%
June 1984	Survey conducted for Traffic Safety Committee	80%
Nov. 1984	Transport Canada Annual Survey	62%
June 1985	Road Safety Research Unit Survey	66%
Nov. 1985	Transport Canada Annual Survey	54%
May 1986	PRE-STEP Survey	58%
June 1986	First POST-STEP Survey	76%
Aug. 1986	Second POST-STEP Survey	70%
Nov. 1986	Transport Canada Annual Survey	61%

Table 2.1. Estimates of Shoulder Seat Belt Use by Drivers in Manitoba

In the survey conducted by the RSRU, seat belt use rates were observed to be higher in passenger cars compared to light trucks or vans; greater for females than for males; and greater for older drivers than younger drivers (Appendix A).

2.1) SUMMARY AND CONCLUSIONS

It is evident that seat belt use rates in the general motoring population have increased significantly from the 5 to 10% rates prior to the introduction of the legislation. Between enactment of the law on January 1, 1984 and the beginning of its enforcement on April 1, 1984, seat belt use rates were estimated to be approximately 35%. Immediately after enforcement of the legislation began, seat belt use rates peaked at approximately 80%. However, in the absence of a rigorous enforcement program or a comprehensive education publicity campaign on the use of seat belts, use rates declined to approximately 55%.

As a result of the STEP program, in the spring of 1986, seat belt use rates again approached 80% but declined to 61% according to the most recent survey in November, 1986. This decrease in seat belt use was not unexpected. It has been generally concluded that attempts at behavior modification through single efforts, without subsequent enforcement and educational programs, are unlikely to produce significant long term benefits (28). However, given the experience in other Canadian provinces, it is conceivable that overall use rates are above what they would have fallen to had the STEP campaign not been introduced.

Although seat belt use rates have increased, compliance remains below the 80% objective set by the Federal-Provincial Cooperative Road Safety Program. To achieve this objective, additional STEP Programs will be needed to stimulate public perception regarding the benefits of seat belts and to underscore the determination to increase seat belt use rates.

3) EFFECTS ON MOTOR VEHICLE OCCUPANT INJURIES

3.1) POLICE ACCIDENT REPORTED DATA

A frequently used source of information respecting motor vehicle collisions and injuries is data compiled from the police accident report. In Manitoba, collision data bases are developed from this report by both the provincial Motor Vehicle Branch and by the City of Winnipeg Streets and Transportation Department.

To assess the impact of seat belt use legislation in Manitoba from police accident reported data, several sources of information were used. These included 1) the annual provincial reports published by the Department of Highways and Transportation, 2) information provided by the Canadian Conference of Motor Transport Administrators (CCMTA), 3) analysis conducted by the Road Safety and Motor Vehicle Regulation Directorate utilizing the Traffic Accident Information and Data (TRAID) system, and 4) from analysis of the Manitoba accident data file conducted by the RSRU.

Figure 3.1 illustrates the number of national motor vehicle injuries between 1980 and 1985 and the number of injuries in the Province of Manitoba. All injuries were indexed according to the number of incidents which occurred in 1981.

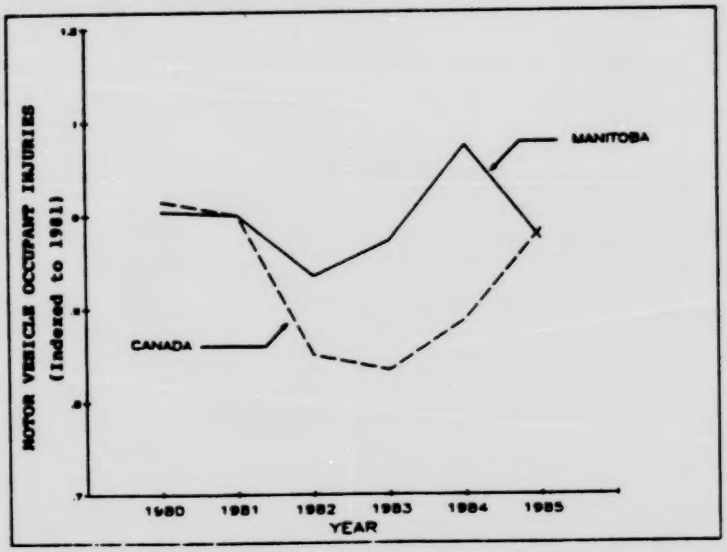

Figure 3.1. Motor vehicle occupant injuries in Manitoba and Canada between 1980 and 1985. Source: CCMTA data provided by the Road Safety and Motor Vehicle Regulation Directorate.

It is evident that, nationally, the number of motor vehicle occupant injuries during 1982 and 1983 was more than 16% less than the number of injuries in 1980 and 1981. During 1984 and 1985 it is also evident that injuries have been increasing and approaching the number recorded in 1980. The unprecedented reduction which occurred during 1982 and 1983 has been largely attributed to the economic recession during that period.

Figure 3.1 also indicates that a similar dramatic injury trend for the Province of Manitoba was not observed. Although a complete economic analysis was not conducted for the purposes of this study, it is suggested that principal measures of economic activity (eg. unemployment and employment rates) between 1980 and 1985 also indicate that Manitoba did not experience an economic recession as severe as the one experienced by several other provinces.

Changes in the number of injuries to other road users is presented in Appendix B. While the absolute number of vehicle occupant injuries was observed to decrease nationally during the five year period, bicyclist and motorcyclist injuries actually increased. In Manitoba, however, pedestrian injuries remained relatively constant, motorcyclist injuries decreased while the number of bicyclists injured showed no trend. Hence, estimating the benefit of seat belt use to vehicle occupants in Manitoba based on injury trends experienced by other road users was not considered appropriate (Appendix C). It could also be argued that the use of motorcyclist injury data would be an inappropriate control group since mandatory helmet legislation was introduced at the same time as the seat belt use law.

To further assess the motor vehicle occupant injuries in Manitoba, the number of vehicle occupant injuries was compared to two control groups 1) all provinces and 2) to British Columbia, Alberta, Saskatchewan, Ontario and Quebec. This data, is presented in Table 3.1, and can be interpreted in several ways. Although injuries in Manitoba have increased by 7% during the two year post-legislation period, this is less than the increase observed if all injuries nationally are considered (11%) and less than the number of injuries in the other control group (13%). Therefore, it could be inferred that motor vehicle occupant injuries in Manitoba actually decreased by at least 4% compared to the number of injuries which might have been expected based on the number of national motor vehicle occupant injuries.

	Two Year Period			Percent Change		
Jursidiction	80/81	82/83	84/85	84/85 vs 82/83	82/83 vs 80/81	84/85 vs 80/81
Manitoba	9,195	9,067	9,724	+ 7%	- 1%	+ 6%
All Provinces	215,301	179,809	200,025	+11%	-16%	- 7%
Selected Provinces	204,765	159,333	179,635	+13%	-22%	-12%

Table 3.1. Estimates of annual motor vehicle occupant injuries. Selected provinces include British Columbia, Alberta, Saskatchewan, Ontario and Quebec. Source: Data from the CCMTA provided by the Road Safety and Motor Vehicle Regulation Directorate.

However, while motor vehicle occupant injuries decreased by over 20% in provinces west of and including Quebec during 1982 and 1983, motor vehicle occupant injuries in Manitoba remained essentially constant. This suggests that the factors which may have led to a decrease in injuries nationally

during 1982 and 1983 did not have the same effect in Manitoba. Thus the apparent benefits of legislation in Manitoba shown in Table 3.1 (7% vs 13%) could be attributed to the fact that injuries in other provinces would be expected to increase more than in Manitoba (during 1984/1985) because injuries in the other provinces in 1982/1983 were inordinately low. This anomaly is further illustrated in a comparison of the change in motor vehicle occupant injuries in 1984/1985 with 1980/1981 (final column). Using this comparison, Manitoba injuries appear to have increased by 18% over the total number of injuries in British Columbia, Alberta, Saskatchewan, Ontario and Quebec.

Table 3.2 summarizes the absolute changes in the number of motor vehicle occupant injuries relative to the two control groups. It is shown that relative to national estimates of motor vehicle occupant fatalities, vehicle occupant injuries in Manitoba decreased during the post-legislation period when compared to the two year pre-legislation period. However, if the two year post-legislation data is compared to injury data from 1980/1981 it is evident that injuries in Manitoba have actually increased relative to the absolute changes in injuries in the other two control groups.

Control	Absolute percent change in motor vehicle occupant injuries in Manitoba	
	Two year post-legislation vs two year pre-legislation	Two year post-legislation vs 1980-1981
All provinces	-4%	+13%
Selected provinces	-6%	+18%

Table 3.2. Absolute percent changes in motor vehicle occupant injuries in Manitoba. Selected provinces included British Columbia, Alberta, Saskatchewan, Ontario and Quebec.
Absolute percent change is defined as;

$$\text{Absolute percent change} = \left(\Delta \text{occupant injuries}\right)_{\text{Manitoba}} - \left(\Delta \text{occupant injuries}\right)_{\text{Control}}$$

Two factors concerning the police accident report data base prevented further analysis. First, inconsistencies in reporting and data collection methods made it impossible to determine national injury statistics in terms of injury severity and type of road user. Also, it is suggested that changes in the number of injuries reported may not be an accurate measure of the number of similar injury producing events which were actually occurring on the road network. For example, while the number of injuries in Ontario appeared to have increased significantly, it was shown that this was attributable mostly to an increase in the number of minor injuries which were reported. These injuries are most influenced by a multitude of non-collision related factors.

Second, on January 1, 1984, the system whereby motor vehicle collisions in Manitoba are reported to police changed substantially. Not only did the report form and the definition of injury change, but the police officer himself was required to complete the report whereas previously, it was completed by the involvee.

In conclusion, data sets based on police accident reports could not be used to adequately assess the effect of mandatory seat belt use legislation in Manitoba due, in part, to changes which have occurred in the system of reporting collisions during the post-legislation period, and to basic inadequacies in the information system itself.

3.2) ANALYSIS OF HOSPITAL ADMISSIONS

Methodology

To assess the effectiveness of the seat belt use law on the frequency and distribution severity of injuries sustained by motor vehicle occupants, a time comparison study of persons admitted to hospital following a collision was conducted. This analysis compared the hospital admissions occurring during the 24 month period prior to the introduction of legislation to the 24 month period following its introduction. All hospital admissions in the province were included in the comparison.

The data base used was the computerized records of hospital admissions maintained by the Manitoba Health Services Commission. Since 1982 these records have described the injuries sustained by each admitted person according to the Clinical Modification of the 9th Revision of the International Classification of Diseases (ICD9CM)(29). Persons involved in a motor vehicle collision are identified by a specific ICD9CM code or "E code."

The ICD9CM manual, published in 1980 by the National Centre for Health Statistics, replaced two other scales (ICDA-8 and the hospital adaptation H-ICDA-8). With the introduction of the most recent version, the injury description became more specific and thus allowed a more detailed use of the manual in the areas of detailed classification of morbidity data, medical case and ambulatory review and in the area of basic health statistics. Although the ICD9CM coding manual adequately characterizes most injuries, it does not describe the severity of the injury nor does it easily identify the body region and organ for each injury.

To provide persons involved in motor vehicle collision research with a uniform system for rating the severity of injuries, the first Abbreviated Injury Scale (AIS) was published in 1971. With subsequent revisions in 1976, 1980 (30) and 1985, the AIS has become the internationally recognized and accepted measure of injury severity. The AIS system assigns a relative measure of severity of between 1 (lowest) and 6 (highest) to each injury sustained by an injured person. The description of each severity code is as follows;

AIS	SEVERITY CODE
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury, virtually unsurvivable

A second injury coding system which can be applied to the ICD9CM injury description is the Occupant Injury Classification (OIC). The OIC system was developed for crash investigators and researchers to categorize accident injuries so that specific injuries may be correlated to injury sources or contact points in the interior of the vehicle (31). The OIC consists of a string of four characters which identify the body region, the aspect, the type of lesion and body system or organ affected. Both the collision investigation teams in the United States (NASS) and the University based investigation teams in Canada have been using the OIC system with the 1980 version of the AIS to code injuries sustained by persons involved in the collisions investigated.

To use the hospital admissions data to evaluate either the seat belt or motorcycle helmet use legislation, a conversion table was developed by the authors which assigned, to each of the over 2000 ICD9CM codes or rubrics, a string of six alpha numeric characters describing the ISS body region, the four digit OIC code and injury severity as defined by the 1980 version of the AIS. A prime objective in the development of this conversion table was to follow, as closely as possible, the interpretation of injury severity as defined by the AIS 1980 coding manual. Clinical interpretations of the relative importance of individual measures of injury severity (threat to life, energy dissipation or permanent impairment) were not permitted.

The first phase in the development of the conversion table involved a frequency analysis of the different ICD9CM injury codes assigned to the persons in the Manitoba hospital admissions data set. The purpose of this task was to assist in the interpretation of some ICD9CM coding descriptions and to identify the magnitude of any inconsistency which may arise if there was difficulty in ascribing a particular code to an ICD9CM injury description or rubric.

Once the most specific rubrics were coded, the remaining rubrics were assigned ISS/OIC/AIS codes after a joint review by the authors (a non-clinician and a surgeon/traumatologist actively involved in acute care services). During this process, coders at a specific health care centre were contacted to determine how particular codes were interpreted by individuals who actually enter information into the data base.

Inevitably there were difficulties in merging the two injury coding systems. In particular, there was poor correlation between the scales of particular injuries (for example duration of loss of consciousness) and nonspecific descriptions of injuries to the abdominal region. These difficulties were addressed by assigning unknown codes and developing a set of injury coding conventions to be adhered to (Appendix D).

Once the conversion table was constructed, computer programs utilizing the SAS statistical analysis package were developed to convert the primary data into a useable format. Additional programs were written to calculate measures of overall severity in terms of the Injury Severity Score (ISS) (32) and the Probability of Death Score (PODS)(33). The validity of the data system in terms of coder and intercoder reliability was evaluated by the authors and by other researchers conducting similar analysis at the University of Manitoba (34) and considered to be adequate for the purposes of this study.

Results

Using the modified hospital admissions data base, the number of motor vehicle occupants determined to be injured following a motor vehicle collision and admitted to hospital was estimated and is presented in Table 3.3. It was observed that the number of motor vehicle drivers and passengers sustaining injuries greater than AIS 1 injuries had changed by 1% and -7% respectively in the two year post-legislation period compared to the two year pre-legislation period.

The number of all motor vehicle occupants sustaining injuries equal to or greater than AIS 2 decreased by 5% while the number sustaining an AIS $\geq$ 3 injury increased by 3%. The number of bicyclists and pedestrians sustaining injuries equal to or greater than AIS 1 injuries increased by 25% and 8% respectively.

Relative to the number of injured pedestrians and bicyclists, the number of injured motor vehicle occupants decreased during the post-legislation period compared to the pre-legislation period. The 5% reduction in the number of admitted motor vehicle occupants is contrary to the results of an analysis of police reported injuries where the frequency of injured motor vehicle occupants was observed to increase by 7%. This suggests that while the frequency of accidents and police reported injuries may have increased, increased seat belt use may have arrested or reversed the upward trend when the more serious injuries are considered (those persons requiring admission to hospital).

Road User	AIS $\geq$ 1 Injuries			AIS $\geq$ 2 Injuries			AIS $\geq$ 3 Injuries		
	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
MV drivers	774	783	+ 1%	572	551	- 4%	250	264	+ 6%
MV passengers	753	702	- 7%	541	511	- 6%	227	226	-
MV occupants	1527	1485	- 3%	1113	1062	- 5%	477	490	+ 3%
Bicyclists	68	85	+25%	56	72	+29%	24	34	+42%
Pedestrians	389	420	+ 8%	388	362	- 7%	184	183	-
Non occupants	457	505	+11%	394	444	- 2%	208	217	+ 4%

Table 3.3. Number of persons admitted to hospital by maximum severity of injury

To assess the change in the number of injuries to various body regions, only those injuries with an AIS severity greater than or equal to 2 were considered. AIS 1 injuries were excluded because of the minor nature of their severity and because it was felt that they are not uniformly reported. (In cases involving multiple severe injuries it is less likely that an AIS 1 injury would be reported compared to a person who sustains only multiple injuries.)

Table 3.4 describes the absolute number of AIS $\geq$ 2 injuries to a particular body region sustained by all motor vehicle occupants. Overall the number of injuries during the post-legislation period was 6% less than during the pre-legislation period. If the absolute number of injuries during the post-legislation period is compared to the pre-legislation period, injuries to the head decreased by 8% while injuries to the face and neck decreased by 39 and 12 percent respectively. For drivers the reduction was head 11%, face 47%, and neck 15%. Chest injuries increased by 39% and there was a 5% increase in injuries to the abdomen.

	Motor Vehicle Drivers			Motor Vehicle Passengers			All Motor Vehicle Occupants		
Body Region	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
Head	294	262	-11%	243	230	- 5%	537	492	- 8%
Face	57	30	-47%	42	30	-29%	99	60	-39%
Neck	54	46	-15%	41	38	- 7%	95	84	-12%
Shoulder	73	63	-14%	50	54	+ 8%	123	117	- 5%
Upper Extrem.	90	77	-14%	80	89	+11%	170	166	- 2%
Chest	63	95	+51%	46	56	+22%	109	151	+39%
Back	66	69	+ 5%	66	47	-29%	132	116	-12%
Abdomen	75	78	+ 4%	61	65	+ 6%	136	143	+ 5%
Pelvis	60	62	+ 3%	77	61	-21%	137	123	-10%
Lower Extrem.	118	135	+14%	147	106	-28%	265	241	- 9%
Total	950	917	- 3%	853	776	- 9%	1803	1693	- 6%

Table 3.4. The number of injuries (AIS $\geq$ 2) to specific body regions sustained by motor vehicle occupants during the two year pre-legislation period compared to the two year post-legislation period.

To determine the possible benefits of trade-offs between injuries to various body regions, the proportion of injuries to a specific body region was tabulated (Table 3.5). During the pre-legislation period head, face and neck injuries represented 43% of all injuries sustained by motor vehicle drivers, compared to 38% in the post-legislation period. Similarly, a greater proportion of chest and abdominal injuries was observed during the post-legislation period. This trend in the distribution of injuries is in the direction expected and desirable. That is, with increased seat belt use, there is a reduction in head injuries, of which only a small proportion can be treated, and an increase in injuries to the abdomen and chest which are eminently treatable.

Compared to the number of injuries to a specific body region which would be expected if the proportionto all injuries remained constant, it was shown that driver head and face injuries decreased by 3% during the post-legislation period. Injuries to the chest and abdomen increased by 3 and 1% respectively.

While changes in the frequency and distribution of injuries to passengers is also presented in Table 3.5, interpretation is difficult because of the random yearly variation in the number and the inability to separate rear seat passengers from those in the front.

Body Region	Motor Vehicle Drivers			Motor Vehicle Passengers			All Motor Vehicle Occupants		
	Pre Leg. (%)	Post Leg (%)	Change	Pre Leg. (%)	Post Leg (%)	Change	Pre Leg. (%)	Post Leg (%)	Change
Head	31	29	-3	28	30	+2	30	29	-1
Face	6	3	-3	5	4	-1	5	4	-1
Neck	6	5	-1	5	5	-	5	5	-
Shoulder	8	7	-1	6	7	+1	7	7	-
Upper Extrem.	9	8	-1	9	11	+2	9	10	+1
Chest	7	10	+3	5	7	+2	6	9	+3
Back	7	8	+1	8	6	-2	7	7	-
Abdomen	8	9	+1	1	8	+7	8	8	-
Pelvis	6	7	+1	9	8	-1	8	7	-1
Lower Extrem.	12	15	+3	17	14	-3	15	14	-1

Table 3.5 Proportion of injuries (AIS $\geq$ 2) to specified body regions, and the change in proportion during the pre-legislation and post-legislation periods.

3.3) SUMMARY AND CONCLUSIONS

The frequency of non-fatal motor vehicle occupant injuries was considered using the police accident reporting system and a system developed by the RSRU to examine hospital admissions in the Province of Manitoba.

It was determined that compared to the number of national police reported motor vehicle injuries in the two year pre-legislation period, injuries in Manitoba decreased in the two year post-legislation period. However, compared to occupant injuries recorded in 1980/1981, and non-occupant injuries, police reported injuries in Manitoba actually increased during the post-legislation period.

Using the converted hospital admission data base it was observed that the number of persons sustaining AIS $\leq$ 2 injuries decreased by 5% compared to the pre-legislation period. The absolute number of injuries sustained by those injured decreased by 6%. Considering the overall collision and injury trend documented by examining police reported data suggested that

injuries should have increased, the reduced number of serious injuries requiring hospital admissions can probably be attributed to increased use of seat belts.

A change in the frequency and distribution of injuries sustained by motor vehicle drivers was also shown. Head and facial injuries decreased while chest and abdominal injuries increased.

The primary shortcoming of this type of analysis is that the data set used presents information on a set of incidents with a pre-determined outcome, that is, a person is admitted to hospital. Using this methodology the number of persons who were not injured or not admitted during the post-legislation phase because they were restrained cannot be determined. In addition, it is conceivable that although the outcome of an injury-producing collision is known (admission to hospital), the severity of collisions producing injuries in the pre- and post-legislation period may not be equivalent. If seat belt use increases and seat belts are effective in reducing injury, it might be argued that if only hospital admissions are considered the overall severity of injuries could be greater in the post-legislation phase since the severity of collisions producing the admissions is greater.

4) EFFECTS ON MOTOR VEHICLE OCCUPANT FATALITIES

4.1) OVERALL NUMBER OF FATALITIES

The number of motor vehicle occupant fatalities in Saskatchewan, Manitoba, Ontario and nationally is presented in Table 4.1. It is evident upon a cursory examination, that a substantial decrease in the number of fatalities did not occur in the two year post-legislation period compared to the two year pre-legislation period.

Whether the absolute number of fatalities observed was less than the expected number of fatalities, depends on the methods used to estimate the number which would have occurred in Manitoba had the seat belt use legislation not been introduced. An examination of the annual changes in fatalities suggests that the trends observed in Manitoba have been consistent with those observed nationally and in Ontario (Appendix E). However, unlike the number of fatalities in Ontario and nationally, fatalities in Manitoba did not increase in 1985.

Because of the failure to observe a large change in the number of fatalities in Manitoba, an analysis utilizing time trend techniques, econometric modelling, or a comprehensive estimation of trends based on the number of fatalities occurring in other provinces (or the number of other road users) was not conducted for the purposes of this study. It is possible that by utilizing these techniques a small but significant change in the number of motor vehicle occupant fatalities could be shown. However, because of the small number of fatalities, the occurrence of a single event producing multiple fatalities could easily compound any attempt to establish a trend.

Jurisdiction	1980	1981	1982	1983	1984	1985
Manitoba	119	127	102	79	90	84
Saskatchewan	-	198	190	177	163	158
Ontario	1095	1049	783	830	742	835
Canada	-	3875	2927	2904	2880	3123

Table 4.1 Estimates of the numbers of fatally injured motor vehicle occupants. Source: Data from the Canadian Conference of Motor Transport Administrators (CCMTA) provided by the Road Safety and Motor Vehicle Regulation Directorate.

4.2) IN-DEPTH COLLISION INVESTIGATIONS

Although the principle objective in conducting these in-depth investigations was to determine the effectiveness or potential effectiveness of seat belts, an attempt was also made to understand collision kinematics and dynamics and to identify variables which contributed to collision causation. In the final analysis judgements were made by the authors which estimated the number of unrestrained persons fatally injured in a motor vehicle collision who would not have been killed had the available restraint system been used. In addition, examination of collisions involving fatally injured restrained occupants enabled conclusions to be

drawn concerning whether the collision event was survivable, whether the restraint system was used correctly, and whether use of the restraint system may have caused injuries which were greater than injuries which would have been expected had the occupant not been restrained.

o Methodology

Each collision involving a fatally injured motor vehicle occupant occurring between January 1, 1984 and January 1, 1986 in Manitoba was investigated by the RSRU. This investigation typically involved an examination of the scene, an inspection of the involved vehicles, and the acquisition of the relevant medical and autopsy information. Collisions in which it was determined that the occupant 1) died due to a pre-existing medical condition, 2) was the occupant of a vehicle other than a passenger car, light truck or van, 3) occupied a position other than a position within the vehicle's occupant compartment (persons in the box of a pickup) or 4) definitely or probably committed suicide, were excluded from further analysis. After obtaining additional information from the investigating police officer and the report of the investigation conducted by the police traffic analyst a complete collision reconstruction was carried out. This included an estimate of the initial velocity of the vehicles involved, determination of collision severity (in terms of change in velocity and occupant compartment intrusion) and a description of the vehicle and occupant kinematics during the crash phase of the collision.

Following the reconstruction, each collision was independently reviewed by each author to estimate the severity of injuries expected had an unrestrained occupant been restrained, and the severity of injuries expected had the restrained occupant been unrestrained. For those occupants who were unrestrained, the probability of survival if the available restraint system was used was defined as;

$0 \leq 10\%$	Essentially no chance for survival
$10 \leq 30\%$	Survival possible but unlikely
$30 \leq 60\%$	Survival definitely possible
$60 \leq 90\%$	Survival very likely
$90 \leq 100\%$	Survival essentially certain

In this evaluation it was assumed that the occupant restraint system would be correctly worn by the injured occupant.

Where a fatally injured person was restrained, estimates were made to determine whether 1) the use of a restraint system reduced the severity of injuries sustained, 2) had no effect on the severity of injuries or 3) increased the severity of injuries which would have been expected had the occupant been unrestrained. After the independent review of each case, a joint review was undertaken to resolve any differences of opinion that may have existed.

The criteria used to estimate the potential and actual performance of occupant restraint systems was based on four collision related parameters and three occupant specific parameters. The collision characteristics included the direction of principal force applied to the vehicle; the extent of crush to the vehicle structure, the extent of intrusion (either

due to vehicular deformation or intruding objects) into the occupant space and the estimated velocity change during the violent phase of the collision. The applicability of each parameter was considered for each type of collision configuration (frontal impacts, near and far side impacts, rear impacts and rollovers).

The occupant specific parameters included the seat position; the type of occupant restraint device available and the physical characteristics of the occupant (in terms of ability to withstand the forces generated during the collision). In all cases a conservative estimate of potential benefit was made. For instance, in far side down rollover type impacts the likelihood of partial ejection injury was considered to be high, while for side impacts, notwithstanding the change in velocity, contact with the interior of the vehicle or striking vehicle by the near side occupant was considered the primary predictor of outcome.

To allow for a review of cases included in the study, a summary of each incident is presented in Volume II numbers one through three. This summary includes a collision narrative, a detailed scene diagram, and illustrative photographs. Selected case studies from Volume II appear in Appendix F.

o Results

Of the 122 collisions involving 155 fatally injured motor vehicle occupants investigated by the RSRU, 61 were single vehicle[1] collisions while 61 were multi-vehicle incidents. Eighty-four percent of the collisions occurred on the rural road network or on roads which were located within urban limits but which were rural in character. In Table 4.2 it is observed that 69% of the rural collisions between 1600 and 0600 hours involved a single vehicle. In comparison, of those which occurred between 0600 and 1600 hours (day time) 61% involved two or more vehicles. It was also noted that 54% of rural night collisions involved a single vehicle incident where the vehicle rolled over. Table 4.2 also presents the number of fatalities (in brackets) as a function of the location, time and type of collision.

	Urban Collisions			Rural Collisions			Total		
Type of Collision	Day-time	Night-time	Total	Day-time	Night-time	Total	Day-time	Night-time	Total
Single Vehicle	0(0)	7(8)	7(8)	21(24)	33(37)	54(61)	21(24)	40(45)	61(69)
Multi-Vehicle	4(4)	9(9)	13(13)	33(48)	15(25)	48(73)	37(52)	24(34)	61(86)
Total	4(4)	16(17)	20(21)	54(72)	48(62)	102(134)	58(76)	64(79)	122(155)

Table 4.2. Collisions involving injured motor vehicle occupant by collision location, time of day and type of collision. Figures in brackets indicate number of fatalities.

[1]A vehicle is defined as a road motor vehicle. Thus collisions involving a train (4) are considered single vehicle.

The type of vehicles involved in this data set are presented in Table 4.3. It is observed that 44% of single vehicle and 45% of all collisions involved a light truck or van (LTV).

Type of Collision	Collision Involved Vehicles	Urban Collisions	Rural Collisions	Total
Single Vehicle	Passenger car	5 (6)	30 (34)	35 (40)
	Light truck or van	2 (2)	25 (28)	27 (30)
Multi-Vehicle	Car vs car	5 (5)	19 (26)	24 (31)
	Car vs LTV	7 (7)	9 (21)	16 (28)
	Car vs truck	1 (1)	7 (8)	8 (9)
	LTV vs LTV	- -	7 (9)	7 (9)
	LTV vs truck	- -	5 (8)	5 (8)

Table 4.3. Type of collisions by involved vehicles and location of the incident. Figures in brackets indicate number of fatalities.

Tables 4.4 and 4.5 document restraint use by drivers involved in these collisions as a function of location, type of collision and time when the incident occurred. As discussed previously, it is observed that restraint use by drivers involved in fatal collisions is substantially less than those in the general population. It is particularly interesting to note that restraint use by drivers involved in a single vehicle collision was only 21%. In contrast, 52% of all drivers involved in multi-vehicle collisions were found to be utilizing the available restraint system. If drivers in multi-vehicle collisions are classified according to who was most at fault, 39% of the at-fault drivers were restrained while 67% of those not-at-fault were restrained. Table 4.5 also indicates that restraint use by drivers involved in daytime collisions was higher than restraint use by drivers involved in nighttime collisions (1600-0600 hours).

	Urban Collision			Rural Collisions			All Collisions		
Type of Collision	Re-strained	Total	% Re-strained	Re-strained	Total	% Re-strained	Re-strained	Total	% Re-strained
Single Vehicle	1	7	14%	12	54	22%	13	61	21%
Multi-Vehicle									
At Fault Driver	6	12	50%	16	45	36%	22	57	39%
Not at Fault Driver	10	13	77%	25	39	64%	35	52	67%
All Drivers	16	25	64%	41	84	49%	57	109	52%
TOTAL	17	32	53%	53	138	38%	70	170	41%

Table 4.4. Percentage of drivers using the available restraint system by collision location and type of collision.

Time of Collision	Urban Collisions			Rural Collisions			All Collisions		
	Re-strained	Total	% Re-strained	Re-strained	Total	% Re-strained	Re-strained	Total	% Re-strained
Day-Time	4	7	57%	37	82	45%	41	89	46%
Night-Time	13	25	52%	16	56	29%	29	81	36%
Total	17	32	53%	53	138	38%	70	170	41%

Table 4.5. Percentage of drivers using the available restraint systems by location and time of collision.

Thirty-four percent of the 155 fatally injured occupants were restrained by the available restraint device. As indicated in Table 4.6 restraint use was observed to be higher in daytime collisions compared to nighttime collisions, lower in single vehicle collisions compared to multi-vehicle collisions and only slightly higher in urban collisions compared to rural collisions. Restraint use by persons fatally injured in a single vehicle rollover was determined to be only 18%. In addition, only 28% of those persons fatally injured in a collision where a driver was impaired by alcohol were restrained. Fourty-one percent of those involved in a collision where alcohol was not involved were restrained.

Type of Collision	Urban Collisions		Rural Collisions		Total Collisions		
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime	Total
Single Vehicle	-	13%	38%	19%	35%	18%	24%
Multi-Vehicle	50%	56%	46%	32%	46%	38%	43%
Total	50%	30%	42%	24%	43%	27%	34%

Table 4.6. Percentage of fatally injured occupants utilizing the available restraint system by collision location, time of day and type of collision.

o Fatally Injured Unrestrained Occupants

One hundred and two unrestrained occupants were fatally injured in the two year period following introduction of mandatory seat belt use legislation in Manitoba. Clinical estimates of the effectiveness of seat belt use in preventing a fatality were made for 98 cases where insufficient data was available. In 34 cases survival was considered to be essentially certain ($P=0.9 \leq 1.0$) if the occupant had used the available restraint system while in 36 it was considered that there was virtually no chance for survival ($P=0.0 \leq 0.1$). Five cases were identified where survival with a restraint was unlikely ($P=0.1 \leq 0.3$), 10 were considered definitely possible ($P=0.3 \leq 0.6$) while 13 were considered taken highly probable ($P=0.6 \leq 0.9$).

The number of fatally injuried unrestrained occupants expected to survive had the available restraint system been worn was estimated by determining the maximum and minimum number of lives saved in each probability of survival category. The summation of the expected number of lives saved in each category yielded the overall estimate of lives saved.

Based on these clinical estimates, it was determined that between 39 and 57 lives were salvageable had the occupant utilized the available restraint system. This estimate infers that use of seat belt would be 40-58% effective in preventing a fatality to those occupants who were fatally injured during the two years following the introduction of mandatory seat belt use legislation in Manitoba. The potential lives saved and estimates of seat belt effectiveness in preventing a fatality are presented in Table 4.7.

Collision Type	Total Fatalities	Potential Lives Saved	Inferred Seatbelt Effectiveness
Occupants of passenger cars	60	26-32	26-32%
Occupants of LTV's	38	16-23	32-45%
Daytime collisions	43	18-24	23-30%
Night time collisions	55	24-33	31-42%
Single vehicle collisions	49	28-37	40-53%
Multivehicle collisions	49	14-20	16-24%
Single vehicle passenger	28	17-21	59-76%
Single vehicle LTV	21	11-15	54-72%
Passenger vs passenger car	13	6-7	42-56%
Passenger vs LTV	17	5-7	30-42%
Collision involving large trucks	13	2-3	12-26%
LTV vs LTV	6	2	30-40%
Urban collisions	14	5-7	23-34%
Rural collisions	84	37-50	28-37%

Table 4.7 Potential lives saved had unrestrained fatally injured motor vehicle occupants utilized the available restraint system.

Fatally Injured Restrained Occupants - During the 24 month period following introduction of the seat belt law, 53 persons were fatally injured while utilizing their available seat belts. Thirty-eight were wearing a three point manual lap and shoulder belt, fourteen were using a two point manual lap belt, while one was restrained by a diagonal two point passive restraint system. Of primary concern in these crashes was whether the collisions were survivable; and whether injuries sustained by the restrained occupants were greater in the severity those which would have been expected had the occupant not been restrained.

Three Point Restraint Systems - Twenty-eight collisions involving an occupant utilizing a three point restraint system were unsurvivable, including frontal collisions with barrier equivalent velocities exceeding 90 kph which resulted in complete destruction of the occupant's space. In some, the use of the restraint may have reduced the severity of injuries sustained by a body region while the cumulative effect of multiple injuries was enough to cause death.

Seven occupants restrained by a three point restraint system were fatally injured in collisions which were considered to be survivable. The outcome was attributed in part, to advanced age (UOM 521, 530, 950), partial ejection of the driver during a complex rollover sequence, and (UOM 970) partial ejection during a simple rollover (UOM 645). The sixth, also elderly, was wearing the restraint system loosely, thereby allowing her to move forward and strike the dash area during a frontal impact (UOM 559). In the last of this subset the occupant had moved the front seat to the full forward position thus allowing her head to strike the steering wheel. The cause of death was a severe head injury. In each of these incidents, the overall injuries sustained were considered to be less severe than those expected had the victim not been restrained.

Based on investigation and analysis of all collisions involving an occupant wearing a three point restraint system, no case was identified in which use of the occupant restraint system caused injuries which would have been greater than those expected had the occupant been unrestrained. In three cases where the restraint system was improperly used it was evident that a deliberate attempt was made by the occupant to wear the system incorrectly.

Two Point Lap Belt Restraint Systems - All front seat fatalities in survivable collisions occurred when the occupant was partially, or (in one case) completely ejected during a rollover sequence (UOM 526, 664, 710, 722). It was considered highly probable the injuries sustained by these occupants would have been the same had they been unrestrained and that use of a three point restraint system would have significantly increased the chance of survival.

Three rear seat occupants using the available lap belt sustained injuries which were considered to be more severe than injuries which would have been expected had the lap belt not been used. In each case the collision type was a head-on frontal impact. In one case (UOM 603), involving a central frontal impact with a tree, the lap belted male died due to a ruptured aorta while four unrestrained occupants sustained only minor injuries. Prior to impact it was determined that the lap belt was applied correctly over the pelvis but moved up as he submarined due, in part, to the soft bench seat. In the second (UOM 861) a male (age 88) died of massive skeletal and visceral injuries to the chest and abdomen. A 60 year old female (wearing the lap belt correctly) seated beside him also sustained life threatening injuries to a hollow abdominal viscus. The third and final lap belted fatality (UOM 615) was a female (age 59) who died from a ruptured abdominal aorta and laceration of the small and large bowel mesentery. In the first two cases the involved vehicle was a full sized American sedan while the third was a late model mini-van.

These three cases are particularly disturbing because the occupant almost certainly expected the lap belt to provide an uncompromised level of protection in any type of collision. While the occupants may have been utilizing their restraint system improperly, (loosely worn, or placed above the iliac crest over the soft part of the abdomen) this improper use was inadvertent. That is, there was no deliberate attempt to compromise the effectiveness of the restraint system.

Two Point Diagonal Passive Restraint Systems - In the single instance involving a two point passive seat belt the fatally injured occupant was a relatively obese elderly female occupying the front seat of a vehicle which was not equipped with knee bolsters under the front dash area as required by federal safety standards (UOM 530).

4.3) SUMMARY AND CONCLUSIONS

The number of motor vehicle occupant fatalities in Manitoba remained relatively constant during the years 1982-85 inclusive. Failure to observe a substantial reduction in the number of fatalities due to the introduction of mandatory seat belt legislation can probably be attributed to a number of factors. First, the number of fatalities each year is small therefore the total can be significantly affected by the occurrence of a single event resulting in multiple fatalities (UOM 988 involved 7 fatally injured occupants). In addition, random yearly variation in the number of fatalities and the lack of exposure data makes it difficult, if not impossible, to estimate the expected number of fatalities had legislation not been introduced. Secondly, although seat belt use rates by drivers in the general population during the two year period was approximately 60%, only 34% of all fatality injured motor vehicle occupants were restrained. Hence, a great potential exists for future reductions in fatalities through increasing the use of seat belts, in particular by those who are most likely to be involved in a collision.

Based on clinical analysis of fatal motor vehicle collisions during the two year post-legislation period it was determined that between 39 and 57 lives were salvageable if the occupant utilized the available restraint system. The benefits of seat belt use were particularly obvious in a number of fatal collisions with both unrestrained and restrained occupants involved. For example in each of UOM 548, 607, 647, 840 and 879 the unrestrained occupant was fatally injured while the restrained occupant sustained nonfatal injuries.

In other cases, the effectiveness of the seat belt was compromised when it was worn under the arm (UOM 970), worn with excessive slack (UOM 550) and where only the lap portion of a detachable three point system was used (UOM 710). These three instances where the restraint system was mis-used, represent 8% of all restrained fatally injured occupants.

In no case was it determined that the use of the three-point restraint system caused injuries which were more severe than those expected had the occupant not been restrained.

In one case involving a lap belted and unrestrained rear seat occupant sustaining similar exposures to stress in a frontal impact (UOM 603), the

fatally injured restrained occupant submarined under the lap belt causing much more severe injuries than those sustained by the other unrestrained occupants.

In collisions involving a rollover use of a lap belt was shown to reduce the probablity of partial or full ejection compared to unrestrained occupants (UOM 840). However the simple two point lap belt was demonstrated to be less effective in preventing partial ejection that the three-point lap belt (UOM 664, 710). Other cases involving ejection of a lap belt restrained occupant include UOM 722 where the lap belt was worn by an obese occupant and who was completely ejected and UOM 526 where the occupant was partially ejected due to failure of the side door latch on a car manufactured prior to implementation of the Canadian Motor Vehicle Safety Act.

In frontal collisions a correctly worn lap belt may reduce the severity of injuries sustained by a restrained occupant compared to those expected if the occupant was unrestrained (UOM 743). However if the lap belt is improperly applied and worn over bulky outerwear the severity of injuries may be greater than those expected had the restraint not been used (UOM 861).

It is critical that the lap belt be placed low over the upper thighs and bony pelvis (the only structures in the abdominal/pelvic area capable of withstanding the forces of deceleration) and that excessive slack be taken up. This means it must be worn under bulky outerwear. In some vehicles, due of the design and geometry of the lap belt, a deliberate effort may be required to properly position it below the spines of the iliac crest.

5) SEAT BELT USE AND DRIVER RISK TAKING BEHAVIOR

5.1) BACKGROUND

The relationship between seat belt use and driver risk taking behavior may affect the impact of mandatory seat belt use legislation in at least two ways. First, it has been hypothesized that the introduction of mandatory seat belt use legislation has failed to produce the expected reduction in the number of motor vehicle occupant injuries in most jurisdictions because the law succeeds primarily in persuading those drivers who are least likely to become involved in a collision to use the available restraint system. This selective recruitment of seat belt users results in a situation where those law abiding low-risk drivers are wearing seat belts and not becoming involved in a proportionate number of collisions while drivers who are the greatest risk takers remain unrestrained and are over-represented in collisions resulting in injuries and/or death.

This hypothesis has been examined by describing driver risk taking behavior in terms of several measurable driver characteristics and then comparing the risk taking behavior of restrained and unrestrained drivers. For example, Evans (35) examined vehicle following headways in high flow free-way traffic of both unrestrained and restrained drivers in both a regulated and nonregulated environment. He concluded that a smaller percentage of restrained drivers in both regulated and unregulated environments drove at small risky headways. In addition to these types of observational studies attitudinal surveys have been conducted to assess the characteristics of persons who report to be seat belt users. A survey of over 20,000 adults in the United States between 1981 to 1983 (36) indicated that persons who did not use seat belts were more likely to exhibit other non-traffic related risk taking characteristics. Those individuals who did not use seat belts were more likely to be smokers, drunk drivers, chronic or binge drinkers or overweight and physically inactive.

On the other hand, it has been argued that the reason many road safety interventions have not yielded major long lasting reductions in the level of safety afforded to road users is because drivers compensate by changing their risk taking behaviour. It is suggested, for example, that a driver will operate a vehicle at a given level of risk and, when obliged to wear a seat belt to increase his level of safety, will begin to take greater risks while driving (speeding, reducing his headway, driving with less attention).

To examine this hypothesis Peltzman (37) conducted a time series analysis of motor vehicle fatalities before and after the introduction of regulations governing vehicle safety devices in the United States and concluded that while motor vehicle occupant fatalities decreased, the reduction was associated with an increase in nonfatal collisions and pedestrian deaths. Conybeare (38) also showed that after the introduction of mandatory seat belt use legislation in Australia, vehicle occupant fatalities decreased while nonoccupant fatalities increased. He concluded that drivers responded to a reduced risk of injury by increasing their driving intensity and shifting the risk to nonoccupants.

The theory of risk compensation and risk homeostasis (where all safety benefits are converted into risk taking activities) have recently been proposed and discussed by Wilde (39) and Adams (40). However, Evans has argued that there is much evidence refuting the concept of homeostasis and no evidence supporting it within a traffic safety context (41).

5.2) BELT USE AND DRIVER CHARACTERISTICS IN MANITOBA

To assess the relationship between risk taking behavior and seat belt use in a regulated environment in Manitoba results of the June 1985 seat belt survey conducted by the RSRU were examined. During the roadside survey nearly 3,000 observations were made which identified the approximate age, sex and restraint use of the driver as well as the licence plate of the vehicles being operated. With the cooperation of the Province of Manitoba's Driver and Vehicle Licencing Division, the registered owner of the vehicle was identified and driver record obtained.

Given the sex and estimated age obtained from the observational survey, and the sex and age of the registered owner of the criteria vehicle, the observations were matched to create a data set which included data on the driver's driving characteristics and observed seat belt usage.

For the purposes of this study, all commercial vehicles, plate number mis-recordings, non matching age and sex recordings and unknown observations were deleted (Table 5.1).

Observation Type	Restrained		Unrestrained		Total	
	n	%	n	%	n	%
Matched Observations	529	34%	415	34%	944	34%
Mis-Match (Age)	258	17%	230	19%	488	18%
Mis-Match (Sex)	363	23%	197	16%	560	20%
Commercial Vehicle	141	9%	135	11%	276	10%
Record Unobtainable	193	12%	173	14%	366	13%
Licence Plate Error	64	4%	68	6%	132	5%
Total Observations	1,548	56%	1,218	44%	2,766	100%

Table 5.1 Results of matching observational restraint use data to driver record of registered owner of observed vehicle.

In addition, those observations where the driver was unrestrained because a seat belt was not available or where the availability of the restraint system was unknown were also eliminated. As a result, only 32% or 885 of the 2766 original observations were incorporated into the final data set. Although there was obviously some error in matching the appropriate driver record to the observed driver, it was also assumed that this error or mis-classification would be independent of driver restraint usage and that no systematic bias was introduced due to mis-matching of observations.

From the driver record four measures (not necessarily independent) of driver risk taking behavior were selected to assess the relationship between restraint use and risk taking behavior. These measures included the number of collisions recorded on the driver's record, the number of traffic related convictions, number of speeding violations and the amount of fines paid due to speeding and/or other traffic related convictions.

Table 5.2 presents the average number of collisions, traffic related convictions, speeding violations and dollars of fines paid by restrained an ununrestrained drivers. It is evident that for male drivers, the average number of collisions, total convictions, speeding violations and amount of fines paid were greater for unrestrained drivers than for restrained drivers. For instance, unrestrained male drivers averaged 0.25 collisions/driver on their record, while restrained male drivers averaged only 0.16 collisions/driver. This relationship is consistent for all four measures of risk taking behavior. No similar difference in the relationship between seat belt use and measure of risk taking behavior among females was observed.

Sex	Restraint Use	Number of Observations	Measure of Risk Taking Behavior			
			Collisions	Convictions	Speeding Violations	Fines
Male	Restrained	397	0.16	0.71	0.42	$33.45
	Unrestrained	300	0.25	1.25	0.69	$57.78
Female	Restrained	132	0.07	0.34	0.21	$21.90
	Unrestrained	56	0.05	0.32	0.18	$15.98
All Drivers	Restrained	529	0.14	0.62	0.37	$30.57
	Unrestrained	356	0.22	1.11	0.61	$51.21

Table 5.2. Mean number of collisions, convictions, speeding violations and fines by restraint use and driver sex.

An alternative presentation of risk taking behavior and restraint use is given in Tables 5.3 and 5.4. Table 5.3 shows that restraint use by male drivers who had not been involved in a collision was 58% while restraint use by male drivers who had been involved in one or more collisions was 53%. This difference is not statistically significant ($p=0.41$). However, the use of restraints is significantly higher among those drivers who had not been convicted of a traffic related offence ($p=0.005$), had no speeding violations ($p=0.002$), or had not been assessed any monetary penalty for a traffic infraction ($p=0.02$). In a similar analysis of female drivers the trends observed were similar to those observed for male drivers, but the differences in restraint use as a function of risk taking behavior were not statistically significant.

Measure of Risk Taking Behavior	Frequency	Restraint Usage (%)	Level of Significance
Collisions	None ≥ 1 Collisions	58 53	0.41
Convictions	None ≥ 1 Convictions	60 47	0.005
Speeding	None ≥ 1 Speeding Violation	60 45	0.002
Fines	No Fines Paid < $100 in Fines Paid ≥ $100 in Fines Paid	60 44 50	0.02

Table 5.3. Restraint usage vs risk taking behavior by male drivers. The level of significance is determined using the Chi-square statistic.

Measure of Risk Taking Behavior	Frequency	Restraint Usage (%)	Level of Significance
Collisions	None ≥ 1 Collisions	70 75	0.71
Convictions	None ≥ 1 Convictions	71 65	0.56
Speeding	None ≥ 1 Speeding Violation	71 60	0.29
Fines	No Fines Paid < $100 in Fines Paid ≥ $100 in Fines Paid	71 57 73	0.54

Table 5.4. Restraint usage vs risk taking behavior by female drivers. The level of significance is determined using the Chi-square statistic.

To assess the effect of age on the relationship between restraint use and risk taking behavior, the subset of male drivers (n=697) was grouped in terms of whether the driver was less than 25 years of age, between 25 and 50 or over 50 years of age (Table 5.5). Although the same trend was observed in all age categories and in all four measures of risk taking behavior, the difference in restraint use was determined to be statistically significant only for the number of speeding violations and convictions for drivers between 25 and 50, and for speeding violations for drivers over 50 years of age.

Measure of Risk Taking Behavior	Frequency	Restraint Usage (%)		
		Driver Age		
		< 25 Yrs (n=47)	25-50 Yrs (n=454)	> 50 Yrs (n=196)
Collisions	None	64	56	69
	≥ 1 Collisions	63	53	55
Convictions	None	71	58*	70
	≥ 1 Convictions	57	47	53
Speeding	None	67	58*	70*
	≥ 1 Speeding Violations	59	45	30
Fines	No Fines Paid	69	58	70
	< $100 in Fines Paid	50	45	55
	≥ $100 in Fines Paid	65	46	33

Table 5.5. Restraint usage by male drivers as a function of risk taking behavior and driver age (* denotes significant difference at the 95% confidence level).

Table 5.6 presents the odds of risk taking behavior for unrestrained male drivers relative to restrained male drivers by driver age. This analysis suggests that unrestrained male drivers under the age of 25 are 1.2 times as likely to have been involved in a collision compared to a restrained male under the age of 25. Similarly, an unrestrained male over 50 years of age is 5.2 times as likely to have been convicted of a speeding offence than a restrained male in the same age category.

The Mantel-Haenszel (42) estimate of the age adjusted relative odds ratio was used to determine the level of significance for all drivers. This test indicates that for three of the four measures of risk taking behavior, the odds that a restrained male driver would exhibit greater risk taking behavior than a restrained driver were positive and significant. A comparable analysis for female drivers could not be performed due to the inadequate number and distribution of observations.

Measure of Risk Taking Behavior	Estimate of Relative Odds by Driver Age			
	< 25 Yrs	25-50 Yrs	> 50 Yrs	All Drivers
Collision Involvement	1.2	1.0	2.1	1.1
All Traffic Related Convictions	2.1	1.3	2.5	1.5*
Speeding Violations	1.3	1.5	5.2	1.7*
Fines Paid Due to Convictions	1.7	1.3	2.5	1.5*

Table 5.6. Odds of risk taking behavior for unrestrained male drivers relative to restrained male drivers by driver age (* denote significan difference at the 5% level). The Mantel-Haenszel estimate of the age adjusted relative odds was used to determine the level of significance for all drivers.

5.3) SUMMARY AND CONCLUSIONS

An examination of seat belt use and risk taking behavior of drivers in Manitoba suggests that unrestrained drivers take more risks while driving than restrained drivers. Unrestrained drivers are more likely to have been involved in a collision, have a traffic related conviction or speeding violation and are penalized more often than comparable restrained drivers.

The analysis suggests that those drivers who remain unrestrained are most at risk thus are more likely to benefit from use ot the available restraint system. As a result, further incremental increases in seat belt use should produce greater benefits (in terms of injury mitigation) than the same increase at lower levels of use. That is, by increasing restraint use from 70 to 80% the benefits are likely to be considerably greater than those observed when rates increased to 40% from 30%.

Although the introduction of mandatory use legislation has substantially increased seat belt use in Manitoba and caused a positive change in the number and distribution of serious injuries, there remains a large potential for achieving further benefits by increasing rates from the present level.

PART B: THE IMPACT OF MANDATORY MOTORCYCLE HELMET USE LEGISLATION

6) INTRODUCTION

6.1) THE EFFECT OF MOTORCYCLE HELMETS

A review of the scientific literature indicates that, given collisions of the same severity, a motorcycle rider wearing a helmet has a lower probability of sustaining a head injury than a rider not wearing a helmet. In addition, there is no documented evidence which suggests that the wearing of helmets causes more severe injuries than would be sustained by an unhelmeted rider. These observations were supported by the most authoritative work relating to motorcycle collisions and injuries, co-authored by Hurt (42) which was based on the in-depth investigation of over 900 motorcycle collisions.

However, during August 1984, it was argued in a Province of Manitoba court that a motorcycle driver wearing a motorcycle helmet is more likely to become involved in a collision than a driver not wearing a helmet. Therefore, it was suggested that use of a helmet increases the probability of being exposed to an event which may cause injury or death. The major factors which allegedly contribute to the increased risk of becoming involved in a collision are 1) build up of heat causing loss of motor coordination and/or fatigue 2) loss of peripheral vision and 3) loss or attenuation of hearing.

The presiding judge concluded that there was no evidence to support the argument that heat build up is a factor in collision causation, that any loss of peripheral vision would be slight and that while noise attentuation may be a a slight factor in collision causation, there is no evidence to establish this point (43). The technical points of discussion in this case have been presented by Peddar (44).

6.2) THE EFFECT OF MOTORCYCLE HELMET USE LEGISLATION

The most current information concerning the effectiveness of mandatory motorcycle helmet use legislation is based on the impact of the repeal of the mandatory helmet use law in the United States. In 1966 the U.S. federal government (as part of a national road safety initiative) required that all states introduce mandatory helmet use legislation before receiving their allotment of federal safety and highway construction funds. After years of failed judicial challenges to the legislation, the U.S. Congress bowed to State pressure and rescinded the Department of Transportation's authority to assess financial penalties for States not introducing the legislation. As a result of that decision, 28 States either repealed or weakened their mandatory use laws.

The situation wherein approximately half the States changed their mandatory use law while the other half did not presented a unique opportunity to conduct a scientific investigation to assess the effectiveness of a road safety regulation.

Two types of studies were undertaken. The first involved a prospective investigation of the frequencies and distribution of injuries sustained by

motorcyclists in four individual States (45-48). McSwain (49) reported that the results of these studies indicated that a decrease in helmet use was associated with a significant increase in head injuries and deaths. It is important to note that these studies were simple before/after studies which compared the incidence and severity of injuries to motorcyclists over a two year period; one year before and one year following repeal of the legislation. No attempt was made to predict the expected number of injuries based on data collected on other road users or from other geographical regions where a helmet use law was not introduced.

The second type of study undertaken was a retrospective analysis of the number of motorcycle fatalities which occurred throughout the United States following repeal of the legislation. The results of several analyses provided a large variation in estimates of effectiveness. For example, Watson (50,51) suggested that there was almost a 40% increase in motorcycle fatalities due to the repeal, while Chenier (52) estimated the increase to be approximately 28%. On the other hand, a statistical analysis conducted by Adams (53) suggested that little if any change in the number of fatalities could be attributed to repeal of the helmet legislation. These differences in effectiveness estimates are due in part to the statistical methods used, and the means used to establish a trend and predict the number of fatalities in a repeal State had that State not recinded its helmet law.

6.3) STUDY DESIGN

The primary objective of this study was to evaluate the effectiveness of legislation which made the use of helmets mandatory in the Province of Manitoba. To accomplish this task it was considered necessary to 1) establish helmet usage rates by motorcyclists, 2) determine the incidence and severity of injuries sustained by motorcyclists, 3) conduct a prospective in-depth investigation of all collisions involving a motorcycle fatality and 4) conduct an in-depth investigation of a representative sample of nonfatal collisions. All in-depth collision investigations were undertaken during the two year post-legislation period.

To determine helmet use rates by motorcyclists, the computerized records of police reported collisions maintained by the Manitoba Motor Vehicle Branch were analysed for the two year pre-legislation period. To document usage rates in the general motorcycle population during the post-legislation period observational surveys were conducted by the RSRU. The incidence and severity of injuries sustained by motorcyclists was determined using the same police accident reporting system, and the converted hospital admissions data base also used to estimate the effect of seat belts in reducing injury severity to vehicle occupants (described in Part A).

The purpose of conducting in-depth investigations was to gain a full and complete understanding of the characteristics of motorcycle collisions (in terms of collision and injury causation mechanisms) and to be in a position to better assess the significance of any changes in frequency and severity of injuries brought about solely by the use of helmets.

To conduct the fourth task a random sample of injury collisions was selected from a geographic area stratified by police jurisdictions. The

jurisdictions included the City of Winnipeg police force, City of Brandon police force, and the RCMP "D" division subdivisions of Winnipeg (19 detachments) and Brandon (35 detachments). A system was designed so that the RSRU was notified of all police reported injury accidents involving motorcycles. The sample plan, including its sampling intervals, was designed with the assistance of the Road Safety and Motor Vehicle Regulation Directorate of Transport Canada to provide a total of 90 investigations over the two year post-legislation period (Appendix F).

Before the investigation activities began, field data collection forms concerning the motorcycle, the motorcycle rider and helmet were developed by the RSRU (Volume III) and used exclusively in the data collection protocol. Because the scene evidence in motorcycle collisions (eg. roadway markings) is so transitory, arrangements were made which allowed a member of the RSRU to respond on a 24 hour basis to any fatal motorcycle involved collision which occurred in the study area. Furthermore, autopsies on the fatally injured riders were regularly attended by the authors so that specific questions could be put to the attending pathologist thereby assuring that detailed and relevant injury information was obtained.

In-depth collision investigations including interviews with involvees permitted numerous specific issues concerning the rider to be better assessed. For example, rider characteristics such as experience and education were identified. More importantly, the role of a helmet as a possible causation factor was specifically addressed. The authors and investigators had, in addition to the required professional qualifications, considerable experience in the special characteristics of motorcycle collisions and sensitivity to the special problems faced by the rider. Included in the final analysis were 24 fatal and 58 nonfatal in-depth collision investigations.

7) EFFECTS OF MOTORCYCLE HELMET USAGE

7.1) MOTORCYCLE HELMET USE IN MANITOBA

While estimates of seat belt use based on roadside surveys conducted by Transport Canada have been available for a number of years, no similar information on the use of helmets by motorcyclists in the general population during the pre-legislation time period was available. To obtain an estimate of helmet use in the accident involved population, an analysis of the Manitoba police data base was undertaken by the RSRU. Unlike usage data during the post-legislation period, there was no reason to expect that self-reported estimates should be inflated. However, since estimates of use in the pre-legislation period involve the collision-involved population only, and if helmet use is a function of risk taking behavior, then usage rates in the collision involved population would be expected to be less than rates in the general rider population.

To estimate motorcycle helmet use in Manitoba during the post-legislation period two methods were used. First, helmet use in the collision involved population was estimated based on the operator's accident report to police. (Estimates of helmet use by riders involved in a police reported collision during the pre- and post-legislation time periods are presented in Table 7.1).

Injury Severity	1982	1983	1984
Not injured	24%	27%	UNK
Injured (Not Hospitalized)	32%	29%	85%
Injured (Hospitalized)	25%	27%	82%
Fatal	17%	27%	83%

Table 7.1. Helmet use by drivers involved in police reported collisions. Source: Analysis of Manitoba police accident data base by the RSRU.

Second, helmet use in the general rider population was determined by three roadside observational surveys conducted by the RSRU as part of this study. During these surveys, carried out in September 1984, June 1985 and October 1985, helmet use was observed over a total period of 146 hours. The survey site selection criteria was slightly different than those used during the seat belt use survey because sites were selected according to traffic volume so that the number of observations could be maximized. The observations were conducted between 0730 and 2400 hours to provide an estimate of helmet use throughout day and night periods. Over 2000 observations of motorcycle drivers and passengers were made. The result of these surveys is presented in Table 7.2. In addition to noting the frequency of use, observers also identified the type of helmet used (Table 7.3).

Date of Observational Survey	Drivers		Passengers		All Motorcyclists	
	Total Observations	% Using Helmets	Total Observations	% Using Helmets	Total Observations	% Using Helmets
Sept. 1984	401	96%	48	96%	449	96%
June 1985	875	96%	119	93%	1031	96%
October 1985	560	85%	92	96%	652	86%

Table 7.2. Estimates of motorcycle helmet usage by motorcyclists in the general driving population.
Source: Observational surveys conducted by the RSRU.

Date of Survey	Type of Helmet Used	Drivers	Passengers	All Motorcyclists
Sept. 1984	Full Face	58%	44%	57%
	Partial	37%	51%	39%
	Shortee	05%	04%	04%
June 1985	Full Face	53%	39%	51%
	Partial	41%	59%	43%
	Shortee	05%	15%	05%
Oct. 1985	Full Face	52%	32%	49%
	Partial	35%	52%	38%
	Shortee	12%	15%	13%

Table 7.3 Type of helmet worn by helmeted motorcyclists observed in the general driving population.
Source: Observational surveys conducted by the RSRU.

7.2) SUMMARY AND CONCLUSIONS

Based on the best available information, it was estimated that helmet use increased from 25 to 35% during the two years prior to the introduction of mandatory use legislation to between 85 and 95% in the post-legislation period. It is highly probable that this increase in helmet use can be directly attributed to the introduction of manditory helmet use legislation in Manitoba.

8) EFFECTS ON MOTORCYCLIST INJURIES

8.1) POLICE ACCIDENT REPORTED DATA

To assess the changes in motorcyclist injuries in Manitoba compared to other Canadian jurisdictions, information from the CCMTA and the Transport Canada (TRAID) file was examined. Figure 8.1 indicates that the changes observed in the number of motorcycle injuries in Saskatchewan and Manitoba were similar while injuries in Ontario and nationally appear to have increased over the 5 year period. To examine the changes in motorcyclist injuries in Manitoba, two variables which are likely to affect the number of injuries were considered.

First the changes in the weather during the two year pre-legislation and two year post-legislation time period were determined. After weather patterns were characterized in terms of hours of bright sunshine, days with measurable precipitation and the mean minimum and maximum temperature, an analysis of variance model using weather data from the pre- and post-legislation summer months was fit for three geographic regions. The year and month were defined as independent variables. From this analysis, it was determined that the two year post-legislation time period was significantly cooler and wetter than the pre-legislation period in each geographic region. No significant difference in the number of hours of bright sunshine was observed.

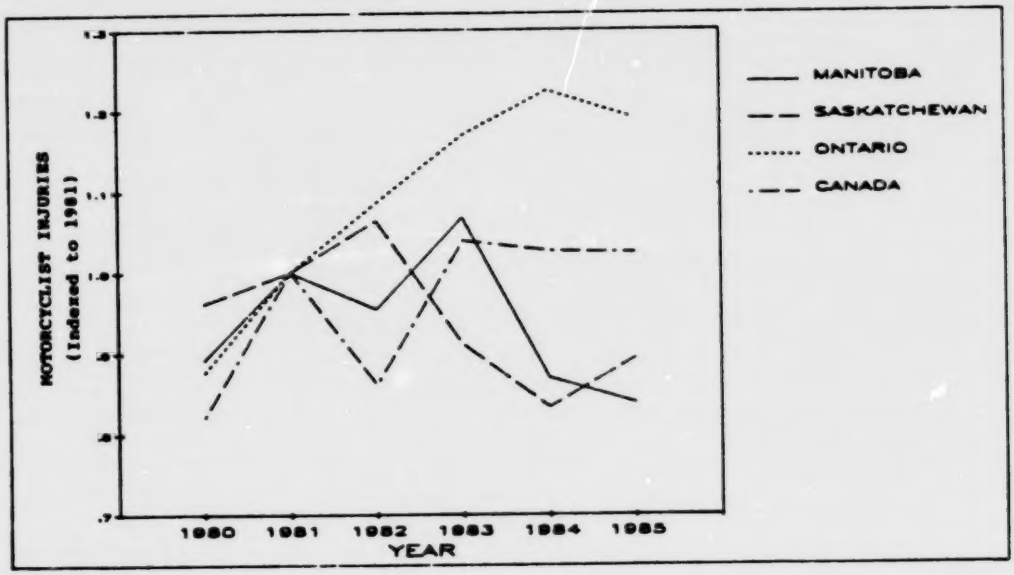

Figure 8.1. Changes in motorcycle injuries in Manitoba, Saskatchewan, Ontario and Canada. All injuries are indexed according to the number of incidents which occurred in 1981.

This difference in seasonal weather patterns may affect the incidence of motorcycle collisions in at least two ways. Because the weather conditions were less favorable during the post-legislation time period, exposure in terms of number of motorcycle rider-kms travelled may have decreased. This decrease in exposure could be expected to reduce the number of collisions, injuries and the collision injury rate (if the rate is calculated in terms of involvement per registered motorcycle). Alternatively, the adverse weather conditions, in particular the additional precipitation, may suggest that those motorcyclists who continue to operate a motorcycle do so while driving at a higher level of risk. Thus, total injuries and collisions may increase along with injury and collision rates if exposure is measured in terms of motorcycle km travelled.

Second, the number of registered motorcycles in the Province of Manitoba was considered. Since there was (3%) increase in the number of registered motorcycles in the two year post-legislation period compared to the two year pre-legislation period, it is highly probable that the decrease in collisions cannot be attributed to a decrease in the number of persons operating a motorcycle.

In summary, it is noted the number of motorcyclist injuries in Manitoba decreased during the two year post-legislation period compared to the two year pre-legislation period. However, property damage only collisions involving a motorcycle in Manitoba (assumed not to be affected by mandatory use legislation) and motorcycle collisions involving injury in Saskatchewan (a province with similar geographic weather and traffic characteristics) also decreased. This suggests that the decrease in rider injuries observed in the post-legislation period may have occurred had the mandatory use legislation not been introduced. Again the lack of adequate information identifying injury severity and the lack of adequate exposure data precluded further analysis of the police reported data base system.

8.2) ANALYSIS OF HOSPITAL ADMISSIONS

The same data set and methods of analysis were used to evaluate the incidence and severity of injuries sustained by motorcyclists as described in Part A. It was hypothesized that if helmet use legislation is effective, then the number of head injuries sustained by motorcyclists should decrease while the number of injuries to other body regions should be unaffected. In addition, facial injuries may be expected to decrease due to protection provided by some helmets (full face), and it has been argued by those opposing helmet use legislation that neck injuries will increase.

The number of motorcyclists admitted to hospital following a motor vehicle collision is presented in Table 8.1. The same trends observed in the police accident reported data are replicated. Whereas the number of police reported property damage only collisions declined by 23% and the number of police reported personal injury collisions declined by 26%, the number of motorcycists whose most severe injury was AIS $\geq$ 1 also decreased by 23% during the post-legislation time period. Similarly, the number with AIS $\geq$ 2 injuries decreased by 23%, while the number with AIS $\geq$ 3 injuries decreased by 15%, compared to the two year pre-legislation period.

Road User	AIS ≥ 1 Injuries			AIS ≥ 2 Injuries			AIS ≥ 3 Injuries		
	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
MC drivers	311	246	-21%	264	205	-22%	118	101	-14%
MC passengers	57	36	-37%	44	32	-27%	24	20	-17%
Motorcyclists	368	282	-23%	308	237	-23%	142	121	-15%
Bicyclists	68	85	+25%	56	72	+29%	28	34	+21%
Pedestrians	389	420	+ 8%	338	362	+ 7%	184	183	-
Nonoccupants	457	505	+11%	394	434	+10%	212	217	+ 2%

Table 8.1. Number of persons admitted to hospital by maximum severity of injury.

To assess the effectiveness of the helmet use legislation, injuries sustained by different body regions were examined. Although the total number of injuries (AIS ≥ 2) sustained by all riders decreased by 24% (Table 8.2), the greatest reduction occurred to the head, face and neck regions. Head injuries were reduced by 54%, face injuries by 44% and neck injuries by 80%.

Body Regions	Motorcycle Drivers			Motorcycle Passengers			All Motorcyclists		
	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
Head	113	48	- 58%	18	12	- 33%	131	60	- 54%
Face	17	10	- 41%	8	4	- 50%	25	14	- 44%
Neck	13	3	- 77%	2	0	-100%	15	3	- 80%
Shoulder	39	30	- 23%	5	3	- 40%	44	33	- 25%
Upper Extrem.	60	46	- 23%	9	4	- 56%	69	50	- 28%
Chest	3	7	+ 67%	2	3	+ 50%	5	10	+100%
Back	18	18	-	0	2	-	18	20	+ 11%
Abdomen	20	30	+ 50%	10	7	- 30%	30	37	+ 23%
Pelvis	18	21	+ 17%	3	6	+100%	21	27	+ 29%
Lower Extrem.	149	127	- 23%	25	22	- 12%	174	149	- 14%
Total	450	340	-24%	82	63	- 23%	532	403	-24%

Table 8.2. Number of injuries (AIS ≥ 2) and percent change sustained by motorcyclists.

Table 8.3 shows that while head injuries to motorcycle drivers declined by 58% during the two year post-legislation period compared to the two year pre-legislation period, injuries to body regions other than to the head, face or neck decreased by only 9%. The reduction in face and neck injuries was comparable to that seen in head injuries.

Body Regions	Motorcycle Drivers			Motorcycle Passengers			All Motorcyclists		
	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
Head	113	48	-58%	18	12	-33%	131	60	-54%
Face & neck	30	13	-57%	10	4	-40%	40	17	-58%
Regions other than head, face or neck	307	279	- 9%	54	47	-13%	361	326	-10%

Table 8.3 Number of injuries (AIS $\geq$ 2) and percent change sustained by motorcyclists.

Table 8.3 presents changes in the frequency of injuries to motorcyclists. Table 8.4 shows the change in distribution of injuries sustained during the post-legislation period. Whereas 25% of all AIS $\geq$ 2 injuries sustained by motorcycle drivers were head injuries in the two years prior to the introduction of the helmet law, only 14% in the post-law period were head injuries. A decrease in the proportion of face and neck injuries was also observed. When all injured riders are considered together, the proportion of head injuries decreased by 10% while the proportion of injuries to body regions other than the head, face or neck increased by 13%.

Body Regions	Motorcycle Drivers			Motorcycle Passengers			All Motorcyclists		
	Pre Leg. (%)	Post Leg. (%)	Change	Pre Leg. (%)	Post Leg. (%)	Change	Pre Leg. (%)	Post Leg. (%)	Change
Head	25	14	-11	22	19	-3	25	15	-10
Face & neck	7	4	- 3	12	6	-6	8	4	- 4
Regions other than head, face or neck	68	82	+14	66	75	+9	68	81	-13

Table 8.4. Proportion and change in proportion of injuries (AIS $\geq$ 2) to specified body regions sustained by motorcyclists.

If it is assumed that injuries sustained to body regions other than the head, face or neck are not related to helmet use, then the number of injuries to those regions could be used to estimate the number of head injuries which would have been expected during the two year post-legislation period. As shown in Table 8.3, 113 head injuries (AIS $\geq$ 2) were sustained by motorcycle drivers, during the two year pre-legislation period compared to 48 in the two year post-legislation period. In addition, 307 injuries to body regions other than the head, face or neck were identified in the pre-legislation period compared to 279 during the post-legislation period.

Compared to the number of head injuries expected, therefore, it was concluded that head injuries to motorcycle drivers decreased by 32% during the post-legislation period. This decrease is highly significant ($p<0.001$). Head injuries sustained by motorcycle passengers also declined but the change was not significant. When all riders were considered as a group, head injuries decreased by 29% ($p<0.001$). In addition, facial injuries to both drivers and passengers decreased by 35% although only the change in injuries to drivers was statistically significant ($p<0.05$).

To test whether differences in the number of head injuries sustained by motorcyclists might be due to an unknown anomaly associated with the hospital data base, or the injury reporting system, injuries sustained by two other groups of road users were examined. The data are presented in Tables 8.5 and 8.6. There was an increase in the number of head injuries to bicyclists and a corresponding increase in the proportion of head injuries. When injuries to pedestrians was considered, both the total number of injuries and the distribution of the injuries sustained was relatively constant over the four year period. When the number of head injuries was compared to all injuries, head injuries to bicyclists increased by 15% while head injuries to pedestrians increased by 7%. Neither change was statistically significant.

Therefore, since no significant decrease in the frequency of head injuries to pedestrians or bicyclists was observed, it is highly unlikely that the decrease in the number and proportion of head injuries sustained by motorcyclists can be attributed to factors other than the legislation. Furthermore, if the number of head injuries sustained by bicyclists and pedestrians is used to estimate the expected number of rider head injuries, the observed decrease in head injuries during the post-legislation period would be greater than 30%.

Body Regions	Bicyclists			Pedestrian			Non-occupants		
	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change	Pre Leg.	Post Leg.	% Change
Head	28	47	+ 68%	134	145	+ 8%	162	192	+ 19%
Face & neck	1	8	+700%	7	12	+71%	8	20	+150%
Regions other than head, face or neck	54	55	+ 2%	493	449	- 9%	547	504	- 8%
Total	83	110	+33%	634	606	- 4%	717	716	-

Table 8.5. Number of injuries (AIS $\geq$ 2) and percent change sustained by bicyclists and pedestrians.

Body Regions	Bicyclists			Pedestrian			Nonoccupants		
	Pre Leg. (%)	Post Leg. (%)	% Change	Pre Leg. (%)	Post Leg. (%)	Change	Pre Leg. (%)	Post Leg. (%)	Change
Head	34	43	+ 9	21	24	+3	23	27	+4
Face & neck	1	7	+ 6	1	2	+1	1	3	+2
Regions other than head, face or neck	65	50	-15	78	74	-4	76	70	-6

Table 8.6. Proportion and change in proportion of injuries (AIS $\geq$ 2) to specified body regions sustained by bicyclists and pedestrians.

8.3) IN-DEPTH COLLISION INVESTIGATIONS; NONFATALLY INJURED MOTORCYCLISTS

During the two years following the introduction of mandatory motorcycle helmet use legislation, an in-depth study of a random sample of motorcycle collisions involving nonfatal injury to riders was conducted. Investigations were conducted primarily to assess collision causation mechanisms associated with motorcycle collisions in Manitoba and to evaluate the effectiveness of motorcycle helmet use on injuries sustained by the riders. In general, a level II type investigation was conducted.The focus of attention in multi-vehicle collisions was the motorcyclist. Typically, the investigation involved acquisition of information obtained by the investigating police officers and relevant injury data. In addition, the collision scene was inspected, and damage to the vehicles and helmet documented, so that vehicle and rider kinematics could be identified. An interview with the rider was also conducted.

All cases were selected according to a prescribed sample plan (Appendix F) designed to provide a representative sample of injury collisions within the province. All police reported motorcycle collisions involving an injury and occurring in each of the four sample areas were logged. This task was achieved through special permission from senior enforcement officers who requested that a copy of the police report face sheet be sent to the RSRU coincident with forwarding it to the Motor Vehicle Branch. Usually, investigation of the collision commenced within 10 days of its occurrence. The final analysis was based on 58 collisions which occurred in the two year period following the introduction of mandatory helmet use legislation in Manitoba.

A narrative for each collision is presented in Volume III of this study. These summaries represent collisions where all information required to complete an adequate investigation was obtained. Inevitably, throughout the selection process, several cases were aborted, often after a considerable amount of time and effort had been expended. Typically, these cases involved motorcyclists who could not be contacted or who refused to cooperate with the investigators.

Based on the indepth investigation of a sample of motorcycle collisions the following obervations are made:

Of those collisions investigated, 35% were single vehicle, 65% were multi-vehicle. Six (22%) of the 37 multi-vehicle collisions involved a motor vehicle (other than a motorcycle) which attempted to turn left in front of the motorcyclist.

Mandatory helmet use legislation was generally not supported by the involved riders. Approximately 86% of the operators expressed a negative opinion towards the legislation. However, compliance was determined to be high as ninety-five percent of all riders were wearing helmets. Prior to the introduction of legislation 39% of the same motorcyclists reported that they did not wear a helmet; 24% reported that they wore a helmet sometimes while only 37% reported that they always wore a helmet.

Thirteen percent of the riders possessed only a beginners motorcycle licence, while 8% did not have any valid motorcycle drivers licence. Twenty-seven percent of the operators involved in a collision were licenced to operate a motorcycle for less than one year. Approximately 50% were licenced to operate a motorcycle for less than two years prior to becoming involved in a collision.

In no case could the use of a helmet be determined to have contributed to causation of the incident (either due to visual restrictions, hearing impairment or heat build up).

In no case did the use of a motorcycle helmet cause injuries which were greater than injuries which would have been expected had the motorcyclist not been helmeted.

There was no evidence to suggest that motorcycle drivers reduced the amount of driving in the two years following the introduction of the helmet use legislation.

8.4) SUMMARY AND CONCLUSIONS

Analysis of police accident data and information based on hospital admissions showed that the number of injured motorcyclists in Manitoba decreased by about 25% during the two year period following the introduction of mandatory helmet use legislation compared to the two years preceding the legislation.

However, how much of this decrease can be directly attributed to the helmet use law remains unknown. While motorcycle registrations increased by 3%, the two year post-legislation period was significantly cooler and wetter than the two year pre-legislation period. In addition, motorcycle collisions involving property damage only (where the use of a helmet should not affect the number of police reported incidents) and the number of motorcycle injuries in Saskatchewan (a province with similar geographic and climatic conditions) also decreased during 1984/85 compared to 1982/83.

Using the converted hospital admissions data base developed by the RSRU, it was determined that while the total number of injuries sustained by motorcyclists decreased by 24%, head injuries showed the greatest decline. Using the number of injuries sustained to body regions other than the head, face or neck as a control, it was determined that the incidence of head injuries decreased by approximately 30% compared to the number expected. It is highly probable that this decrease resulted from the enactment of mandatory motorcycle helmet use legislation in the Province.

Analysis of hospital admissions also showed a decrease in the incidence of face and neck injuries. Indeed, the proportion of injuries to the face and neck compared to all injuries sustained by motorcyclists decreased to 4% during the post-legislation period from 8% in the pre-law period. In addition to the observed reduction of AIS $\geq$ 2 neck injuries, there was no incident where a motorcyclist sustained a cervical spine injury resulting in neurologic deficit in the post-legislation period.

To examine the claim that helmet use contributes to the occurrence of a motorcycle collision and injury, a sample of non-fatal injury collisions was studied in-depth by the RSRU. In none of the cases investigated could it be determined that use of a helmet was a factor in collision causation, or that injuries sustained by helmeted riders were more severe than those expected if a helmet had not been used.

9) EFFECTS ON MOTORCYCLIST FATALITIES

9.1) OVERALL NUMBER OF FATALITIES

The number of fatally injured motorcyclists in Saskatchewan, Manitoba, Ontario and nationally is presented in Table 9.1. There was no substantial change in the number of fatal collisions which occurred in Manitoba or Saskatchewan over the time period presented. However, an increase in the number of incidents in Ontario has occurred. Based on the absolute number incidents involving a fatally injured motorcyclist in Manitoba, there was no evidence that the introduction of mandatory helmet use legislation affected the number of motorcycle fatalities. Because of the small number of incidents involved, the random yearly variation, and the multitude of collision and injury causation variables associated with a fatal motorcycle collision, no trend was expected or observed.

Jurisdiction	1980	1981	1982	1983	1984	1985
Manitoba	17	17	16	15	13	18
Saskatchewan	-	17	20	8	19	13
Ontario	99	108	127	118	142	124
Canada	354	422	422	450	420	416

Table 9.1. Estimates of the number of fatally injured motorcyclists.
Source: Data from the Canadian Conference of Motor Transport Administrators provided by the Road Safety and Motor Vehicle Regulation Directorate.

9.2) IN-DEPTH COLLISON INVESTIGATIONS; FATALLY INJURED MOTORCYCLISTS

Between January 1984 and January 1986, 24 collisions involving 29 fatally injured motorcyclists were investigated by the RSRU. This represents virtually all motorcycle fatalities which occurred in the province during the two year post-legislation period. Of the 29 fatalities (26 males and 3 females), 23 were drivers while 6 were passengers. Only 1 driver was female. Four fatally injured persons were less than 16 years of age (14%), 7 were aged 16-20 years (24%), 12 were aged 21-25 years (41%) and 6 were over 25 years of age (21%). Sixteen collisions (67%) occurred on the rural road network or on roads within urban limits but which were rural in character. Seven of the 8 urban collisions occurred on a major urban arterial, while 1 occurred at a minor residential intersection.

Overall, 12 collisions involved only the motorcycle while 12 involved two vehicles. Not surprisingly, 6 of the 8 urban collisions involved two vehicles. In 4 of the 12 multi-vehicle collisions the other vehicle attempted to complete a left turn in front of the oncoming motorcycle. The motorcycle and other vehicle collided in an intersecting configuration in 4 incidents. Two were head-on collisions and 2 were motorcycle front to rear of car impacts.

Nineteen of the 29 fatalities (66%) were wearing an approved motorcycle helmet at the time of the collision, 8 were unhelmeted. In one case the rider was

wearing an unapproved helmet and in another helmet use could not be determined. Only 10 of 19 riders involved in a rural collision wore an approved helmet, compared to 9 of the 10 for collisions which occurred in an urban area.

Nineteen (54%) of all fatally injured riders were involved in a collision where the motorcycle operator was impaired due to the consumption of alcohol. Twelve of the 19 collisions (67%) involving 13 fatalities which occurred between 1800 and 0600 hours, were alcohol related.

Summaries of these collisions are included in Volume III of this report. Also, Appendix H describes the basic collision and injury characteristics of each collision investigated, and identifies those injuries which were considered to be the primary cause of death.

o Helmeted Fatalities - Nineteen motorcyclists were fatally injured while wearing an approved motorcycle helmet. In addition, 1 fatality involved a motorcyclist wearing a non-approved "pot-type" helmet which was ejected from the motorcyclist's head during the early phase of the collision (UOM 880).

Two deaths were attributed, in large part, to failures within the emergency health care delivery system. In one (UOM 878) the motorcyclist died in a small rural hospital seven hours post-crash due to a mismanaged ruptured spleen. He did not sustain a head injury and was conscious until shortly before death. The second (UOM 929) involved a moderate speed urban incident where the motorcyclist skidded and then slid into the side of a passenger car. He was transported to a regional suburban hospital where liver lacerations as a result of blunt abdominal trauma were diagnosed. He was transferred to a tertiary care facility two days post-crash due to peritoneal bleeding and eventually died 26 days later from sepsis and liver failure.

Five persons wearing helmets (UOM 602, 640, 652, 883 and 910) sustained a fracture dislocation of the atlanto-occipital articulation of the neck (upper cervical spine). In one instance, the neck injury was associated with severe trauma to the head (UOM 640), while in all other cases the deceased also sustained severe life threatening injuries to the chest and/or abdomen. Each was involved in a high speed collision, with another vehicle, which was considered unsurvivable. In three cases the helmet retention system failed during the impact (UOM 602, 850, 883).

In one case (UOM 893) the deceased was wearing a 3/4 type helmet and died due to a severe basal skull fracture caused by an impact to her face, while in another (UOM 799) the helmeted rider died due to drowning. In the remaining cases, 2 fatalities were attributed primarily to head only injuries, 6 sustained severe life threatening injuries to the chest or abdomen while 3 sustained multiple life threatening injuries to both the head and other body regions.

o Fatalities Not Helmeted - Eight fatally injured riders were not wearing a helmet at the time of the collision. In addition, one incident occurred where an extensively damaged helmet was located at the scene (the retention system was unfastened and undamaged) and no tissue was found on the inner liner despite the severe open head injury sustained by the deceased. In this instance (UOM 889) it is highly probable that the deceased was not helmeted.

All unhelmeted fatalities experienced high levels of deceleration and velocity change. Although the cause of death in most instances was due to injuries to the head and other body regions, 2 fatalities were considered potentially salvageable. In the first (UOM 590) the motorcyclist sustained only a severe head injury which may have been prevented had an approved helmet been worn. The second case (UOM 931) occurred in a rural area at approximately 0400 hours. The rider sustained a moderate head injury and a severe pelvic fracture. He was observed to be conscious early in the post-crash phase. Unfortunately, he was transferred from a small community hospital to a regional health care facility without advanced life support measures administered en route. He was pronounced dead shortly after arrival at the regional centre, largely due to blood loss as a result of the pelvic fractures. Failure to provide adequate emergency health care was considered to be a major contributing factor to the fatal outcome of this incident.

9.3) SUMMARY AND CONCLUSIONS

Prior to the introduction of mandatory motorcycle helmet use legislation it was predicted that a significant decrease in the number of fatalities may not be observed. These conclusions were based on an assessment of the multitude of factors relating to fatal motorcycle collisions (including severity) and the relatively few number of incidents which occur on a yearly basis in Manitoba. Therefore, it was determined that in-depth investigations should be conducted to assess the role of a helmet in the outcome of these collisions.

A glance at the injury profile of riders fatally injured during the two year post-legislation period (Appendix H) indicates the extreme severity of the stress producing exposures experienced by all 29. Death usually was associated with more than one critical (life threatening) injury. Nine of the 29 (31%) sustained a ruptured major vessel (heart or aorta) an injury almost never compatible with survival.

It is often not realized that motorcycle riders, while considered vehicle occupants, have no surrounding protective capsule and other safety devices afforded car occupants to absorb impact energy. Hence they are, in fact, unprotected like pedestrians and often made more at risk because they are moving when struck, often fast and in the opposite direction.

Nineteen (66%) of all motorcyclists fatally injured during the two year period following the introduction of mandatory helmet legislation were wearing approved motorcycle helmets. Eight or 28% of the fatalities were known to be unhelmeted.

In no case was it determined that use of a helmet contributed to causation of the collision.

In no case was it concluded that the use of a motorcycle helmet significantly altered the final outcome of the collision. In those with a spinal (neck) injury, it was concluded that use of a helmet did not contribute to the its causation or increase the severity.

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APPENDIX A

RESULTS OF RSRU SEAT BELT SURVEY - JUNE 1985

	All Passenger Cars % Use	Domestic Cars % Use	Foreign Cars % Use	Light Trucks/Vans % Use
All	66	65	69	43
Male	62	60	68	40
Female	74	74	71	64

Table 1. Percent of Drivers Wearing Shoulder Belts in Vehicles Equipped with Shoulder Belts: Sex of Driver vs Type of Vehicle

Age	All Passenger Cars % Use	Domestic Cars % Use	Foreign Cars % Use	Light Trucks/Vans % Use
< 25	60	58	66	35
25-49	66	66	69	44
> 50	70	69	82	44

Table 2. Percent of All Drivers Wearing Shoulder Belts in Vehicles Equipped with Shoulder Belts: Age of All Drivers vs Type of Vehicle

Age	All Passenger Cars % Use	Domestic Cars % Use	Foreign Cars % Use	Light Trucks/Vans % Use
< 25	53	48	66	29
25-49	61	60	67	42
> 50	70	69	89	40

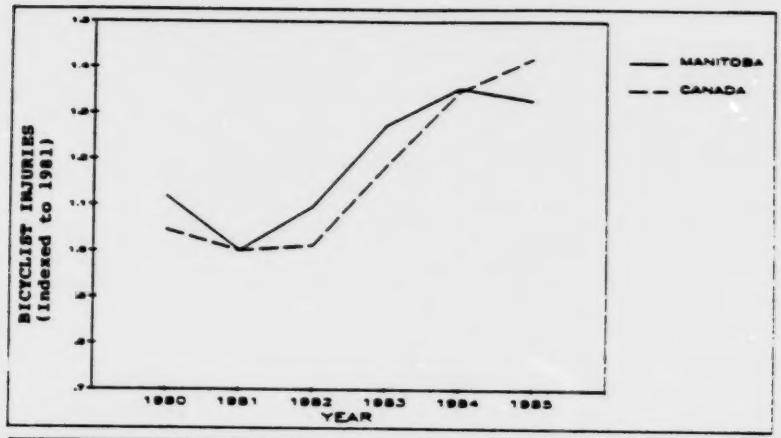
Table 3. Percent of Male Drivers Wearing Shoulder Belts in Vehicles Equipped with Shoulder Belts: Age of Male Drivers vs Type of Vehicle

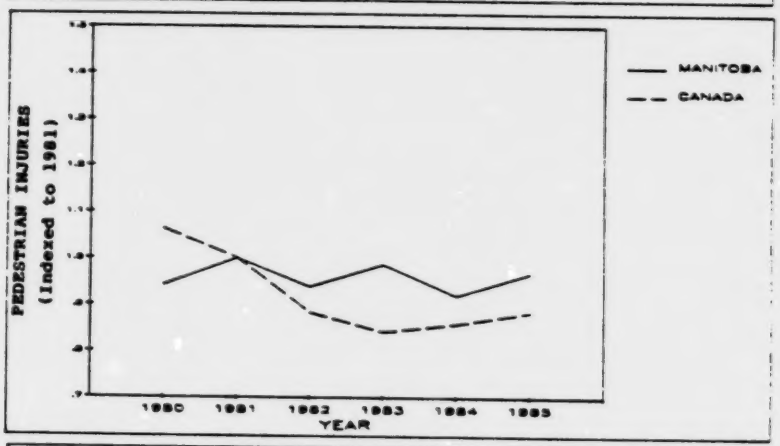
Age	All Passenger Cars % Use	Domestic Cars % Use	Foreign Cars % Use
< 25	69	40	66
25-49	76	77	74
> 50	71	71	69

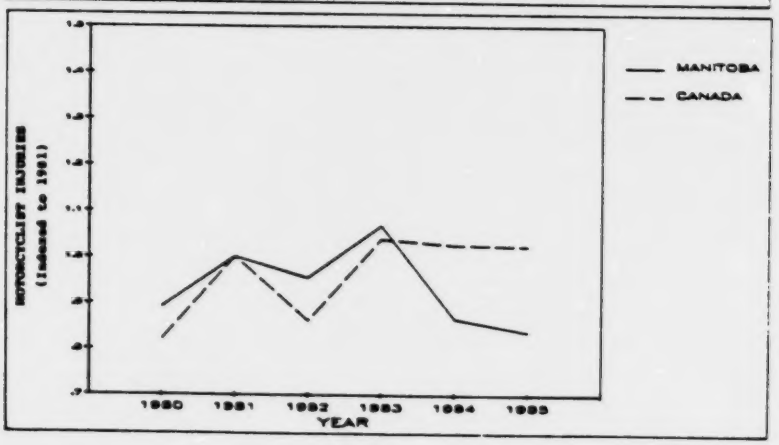
Table 4. Percent of Female Drivers Wearing Shoulder Belts in Vehicles Equipped with Shoulder Belts: Age of Female Drivers vs Type of Vehicle

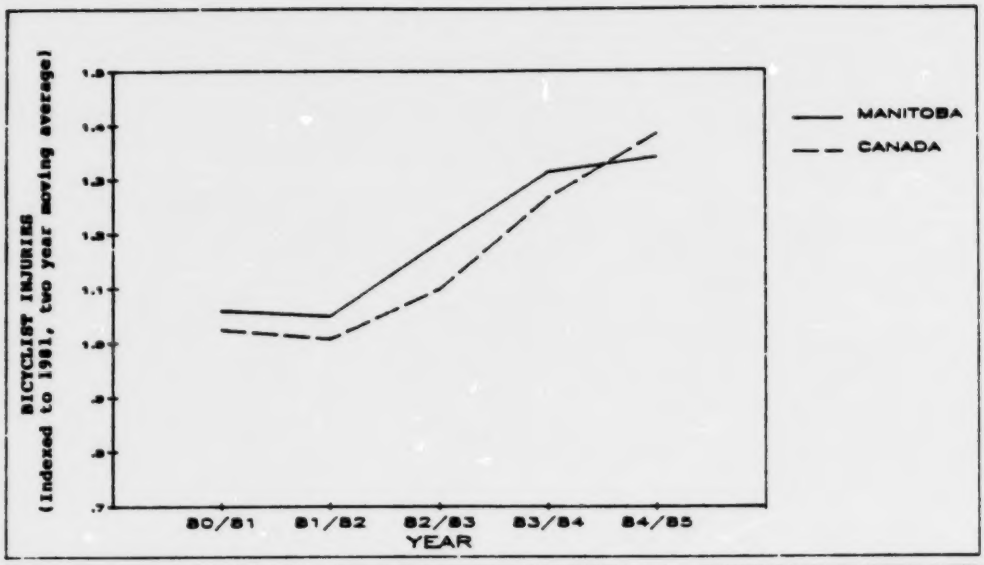
APPENDIX B

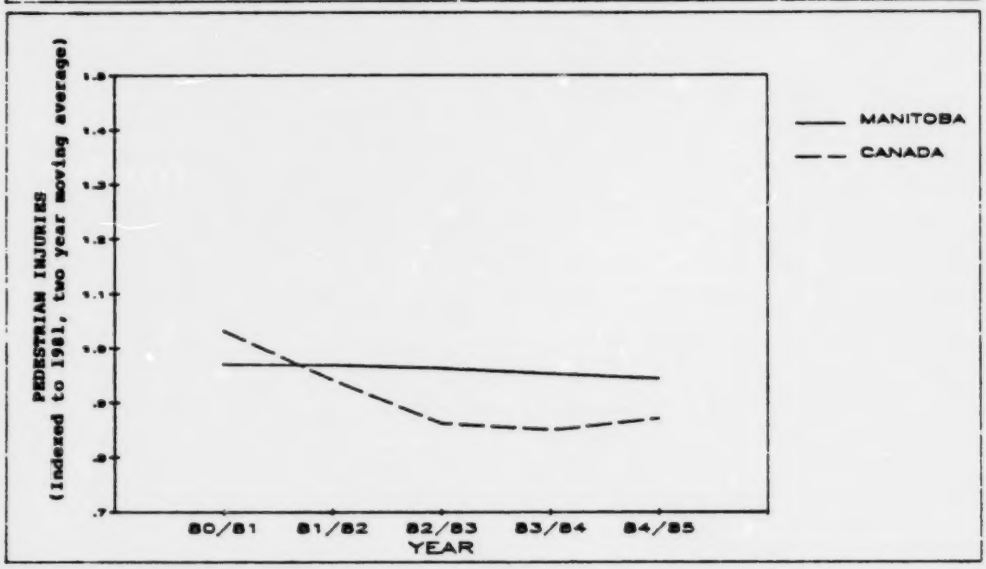
CHANGES IN NON-OCCUPANT INJURIES

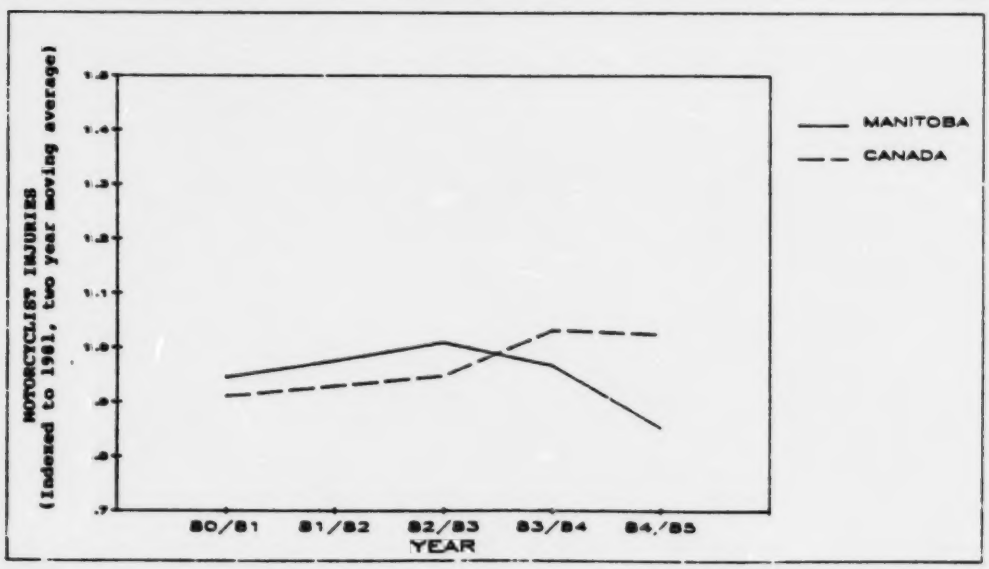







BICYCLIST INJURIES
(Indexed to 1981, two year moving average)
MANITOBA
CANADA
80/81
81/82
82/83
83/84
84/85
YEAR


PEDESTRIAN INJURIES
(Indexed to 1981, two year moving average)
MANITOBA
CANADA
80/81
81/82
82/83
83/84
84/85
YEAR


MOTORCYCLIST INJURIES
(Indexed to 1981, two year moving average)
MANITOBA
CANADA
80/81
81/82
82/83
83/84
84/85
YEAR

APPENDIX C

THE USE OF NON-OCCUPANT INJURIES TO ESTIMATE THE EXPECTED NUMBER OF OCCUPANT INJURIES

Data on non-motor vehicle occupants could be used to estimate the number of expected occupant injuries in Manitoba during the post-legislation period if it is assumed they are affected by the same causation factors. As indicated in Table 1, non-occupant injuries in Manitoba decreased by 13% in the two year post-legislation period while nationally non-occupant injuries increased.

Jursidiction	Non Motor Vehicle Occupant Injuries			Percent Change		
	1980/ 81	1982/ 83	1984/ 85	84/85 vs 82/83	82/83 vs 80/81	84/85 vs 80/81
Manitoba	1,445	1,487	1,301	-13%	+ 3%	-10%
All Provinces	46,517	45,201	48,297	+ 7%	- 3%	- 4%
Selected Provinces	42,976	41,715	42,848	+ 3%	- 3%	-

Table 1. Estimates of annual non-motor vehicle occupant injuries. Selected provinces include British Columbia, Alberta, Saskatchewan, Ontario and Quebec.

Therefore if trends in non occupant injuries are used to predict the expected number of motor vehicle occupant injuries then motor vehicle occupant injuries in Manitoba would be shown to have <u>increased</u> during the two year post-legislation period compared to the two year pre-legislation period. Injuries also increased relative to the number of injuries in 1980/81.

Control	Relative Percent Change in Motor Vehicle Occupant Injuries	
	Two year post-legislation vs two year pre-legislation	Two year post-legislation vs 1980/81
All Provinces	+16%	+19%
Selected Provinces	+10%	+26%

Table 2. Relative percent changes in motor vehicle occupant injuries in Manitoba. Selected provinces included British Columbia, Alberta, Saskatchewan, Ontario and Quebec.

Relative percent changes are defined as;

$$\text{Relative percent change} = \left[\left(\Delta \text{occupant injuries}\right)_{\text{Manitoba}} - \left(\Delta \text{occupant injuries}\right)_{\text{Control}}\right] - \left[\left(\Delta \text{non-occupant injuries}\right)_{\text{Manitoba}} - \left(\Delta \text{non-occupant injuries}\right)_{\text{Control}}\right]$$

APPENDIX D

INJURY CODING CONVENTIONS: ICD9CM CONVERSION TABLE

Head Injuries

- Single ICD9CM rubrics describing skull fractures (8000-80199 and 8030-8039) may be assigned two ISS/OIC/AIS codes representing 1) the skull fracture, and 2) the anatomic or diffuse lesion.

- If only one substantiated anatomic lesion to the brain is noted and the length of unconsciousness is known, the OIC will consist of the four characters describing the injury as specified in the anatomic lesions section. The AIS will be determined by comparing 1) the AIS which accompanies the specified injury in the anatomic lesion section with 2) the AIS of the comparable injury in the diffuse lesions section. The highest of the two AIS scores will be coded.

- The ICD9CM description of unconsciousness is assigned an AIS severity according to the following table:

ICD9CM Description	AIS Severity
unspecified state of consciousness	-
no loss of consciousness	-
< 1 hour loss of consciousness	2
1-24 hours loss of consciousness	4
> 24 hours loss of consciousness	5
loss of consciousness of unspecified duration	2
unspecified concussion	2

- All ICD9CM descriptions of anatomic lesions are assigned an AIS severity of 3. These lesions are coded conservatively because injuries of higher severity, eg. epidural, subdural, intracerebral, or intracerebellar hematoma (AIS 4); or diffuse brain injury (AIS 5) cannot be identified explicity and because an injury of such a severity would likely be described by a loss of consciousness > 1 hour (AIS 4 or 5).

- An open fracture of the base of the skull is considered to be more severe than a closed fracture of the same (AIS 4 rather than AIS 3)

Table 1: Examples of injury coding conventions used during the development of the ICD9CM - ISS/OIC/AIS conversion table: head Injuries.

Spinal Cord Injuries

- o ICD9CM codes specifying fractures of the vertebral column with spinal cord injury (8060-8060) are assigned two ISS/OIC/AIS injury codes representing 1) the fracture of the specified vertebra and 2) the spinal cord injury.
- o The AIS of a spinal column injury (8060-8069 and 8390-8399) when associated with hemiplegia (342) or other paralytic syndromes (3440-3449) is reclassified to an AIS score of 5.
- o The ICD9CM description for spinal cord injury (including injuries associated with open and closed fractures to the cervical and dorsal vertebra) are assigned an AIS severity according to the following table:

ICD9CM Description	AIS Severity
unspecified spinal cord injury	3
complete lesion	5
anterior cord syndrome	4
central cord syndrome	3
other specified spinal cord injury	4

Chest Injuries

- o The AIS of open or closed fractures of the ribs or sternum (8070-8075) when associated with pneumothorax (8600), hemothorax (8604), or pneumohemothorax (8604) is reclassified to an AIS score of 3.
- o If a "flail chest" (8074) is associated with open or closed fractures of the ribs (8070-8072) then the code for fractured ribs is deleted and the code for flail chest is used.

Injuries to the Abdomen & Pelvic Contents

- o Injuries to the gastrointestinal tract (8630-8639), pelvic organs (8670-8679) and other intraabdominal organs (8680-86819) with open wound into cavity, is considered to mean a laceration or puncture of the skin surface.

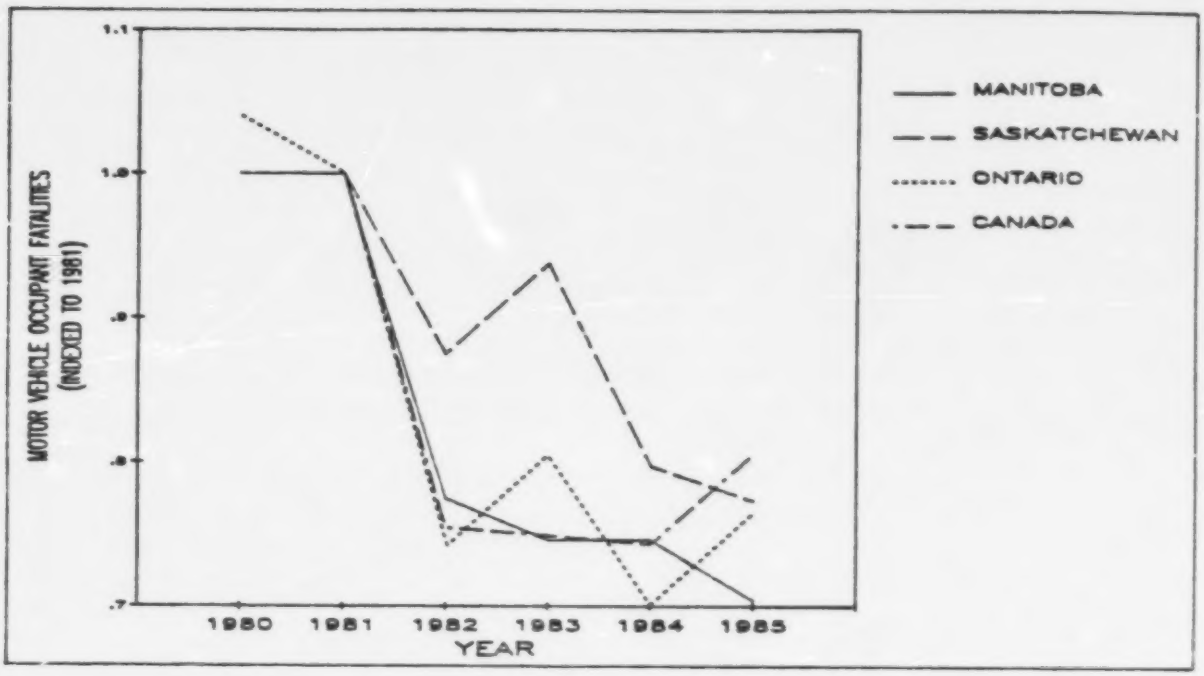
Injuries to the Extremities

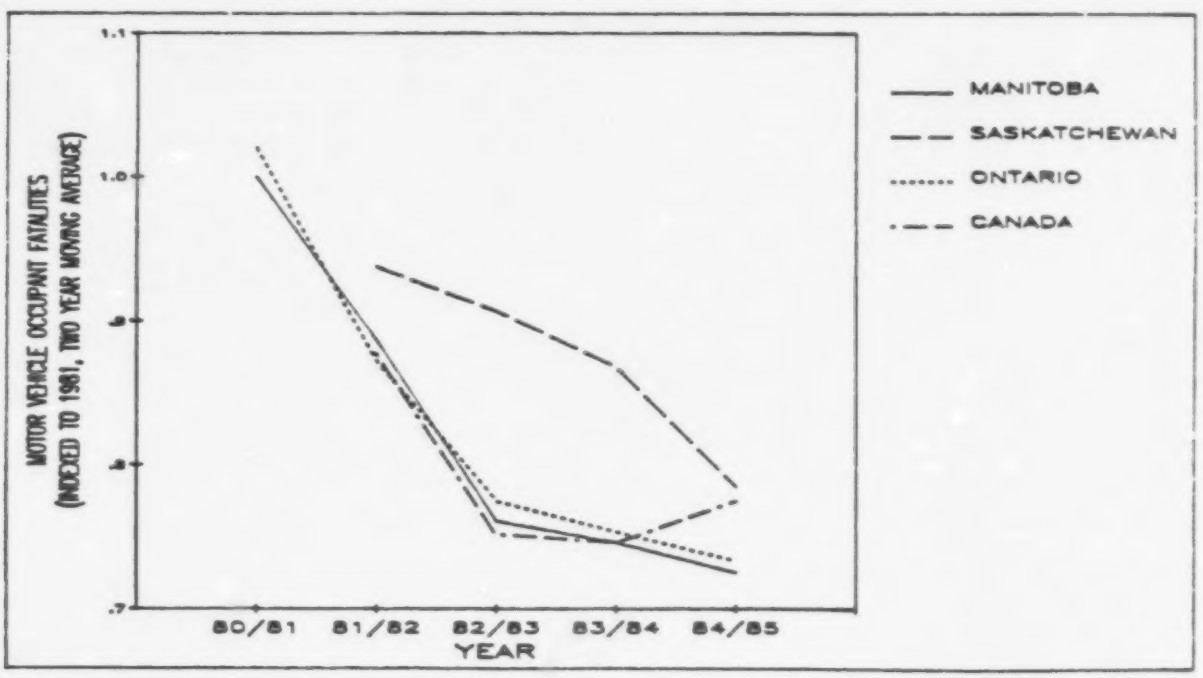
- o Open and closed fractures of the tibia and fibula are considered as two separate injuries and are assigned two ISS/OIC/AIS codes.

Table 2: Examples of injury coding conventions used during the development of the ICD9CM - ISS/OIC/AIS conversion table; spinal cord injuries; chest injuries; injuries to the abdomen and pelvic contents; and injuries to the extremities.

APPENDIX E

CHANGES IN VEHICLE OCCUPANT FATALITIES





APPENDIX F

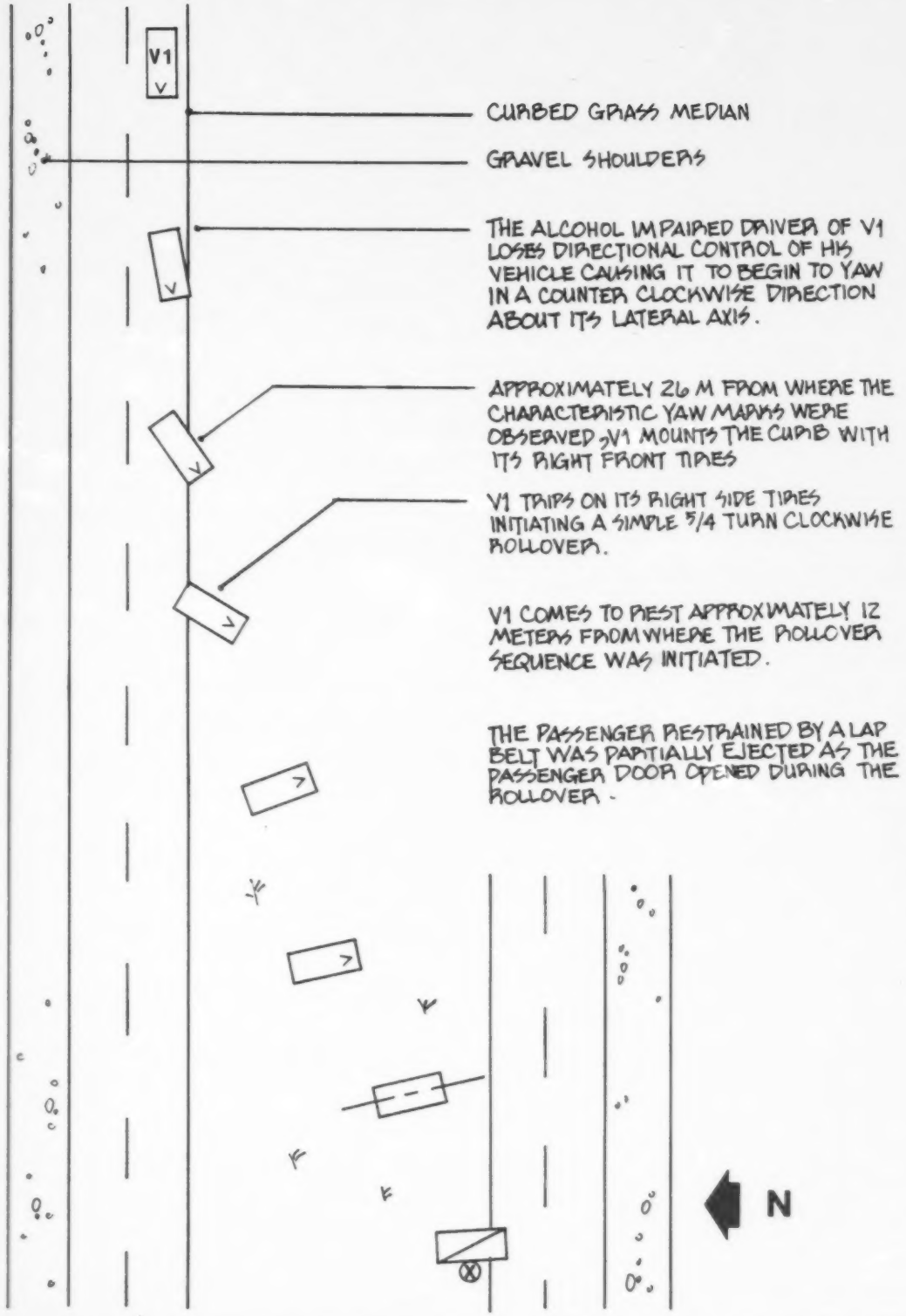
SELECTED CASE STUDIES FROM VOLUME II

This single vehicle rollover collision occurred at approximately 2330 hours on a two way, four lane, median divided, urban arterial. The concrete road surface was in good condition and dry. At the time of the collision visibility was normal under night driving conditions while the roadway was adequately illuminated by artificial lighting.

V1, a 1966 Pontiac two door passenger car, operated by an unrestrained alcohol impaired 23 year old male, was westbound in the right travel lane. The driver was accompanied by a 20 year old male seated in the right front passenger seat. Although the passenger in V1 was utilizing his two point lap belt provided for his seating position, it is highly probable that it was worn loosely.

It is possible that the driver of V1 attempted to shift from second to third gear using the floor mounted gear shifter when he inadvertantly shifted into reverse causing the left rear wheel to lock, causing V1 to yaw in a counterclockwise direction. V1 continued to yaw as it crossed the left travel lane and struck the median curb with its right front tire approximately 26 m from where the driver lost control of his vehicle. V1 had moved onto the grassy median and rotated approximately 135° from its original direction of travel when it tripped on its right side tires. This initiated a simple five quarter turn rollover sequence as V1 rotated in a clockwise direction about its longitudinal axis. V1 eventually came to rest on its right side approximately 12 m from the point where the rollover sequence began.

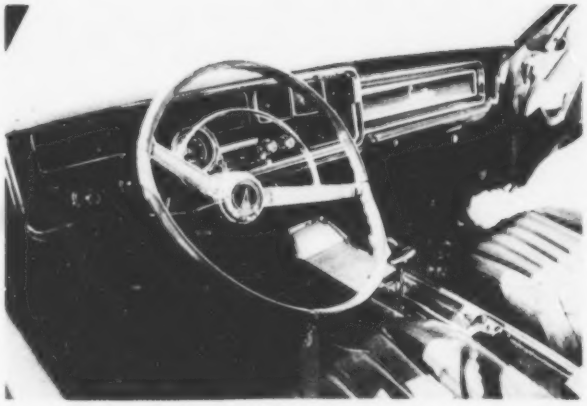
During the rollover the unrestrained driver initially moved right loading the front seat passenger and then moved rearward as the left rear corner of V1 struck the ground. As a result of structural deformation and loading by the two front seat occupants, the passenger side door opened enabling the restrained right front seat passenger to be partially ejected from V1. The passenger was then trapped between the rocker panel and the crushed door as V1 came to rest on its right side. He sustained critical chest (MAIS 4) and abdominal (MAIS 4) injuries and probably died at the scene of the collision as a result of traumatic asphyxia. The driver came to rest in the rear passenger seat area and sustained only minor (MAIS 1) injuries.


V1
CURBED GRASS MEDIAN
GRAVEL SHOULDERS
THE ALCOHOL IMPAIRED DRIVER OF V1 LOSES DIRECTIONAL CONTROL OF HIS VEHICLE CAUSING IT TO BEGIN TO YAW IN A COUNTER CLOCKWISE DIRECTION ABOUT ITS LATERAL AXIS.
APPROXIMATELY 26 M FROM WHERE THE CHARACTERISTIC YAW MARKS WERE OBSERVED, V1 MOUNTS THE CURB WITH ITS RIGHT FRONT TIRES
V1 TRIPS ON ITS RIGHT SIDE TIRES INITIATING A SIMPLE 3/4 TURN CLOCKWISE ROLLOVER.
V1 COMES TO REST APPROXIMATELY 12 METERS FROM WHERE THE ROLLOVER SEQUENCE WAS INITIATED.
THE PASSENGER RESTRAINED BY A LAP BELT WAS PARTIALLY EJECTED AS THE PASSENGER DOOR OPENED DURING THE ROLLOVER.
N

UOM 526
PCS 003

V1 1966 PONTIAC TWO DOOR PASSENGER CAR

DIAGRAM NOT TO SCALE.



PCS 003
UOM 526

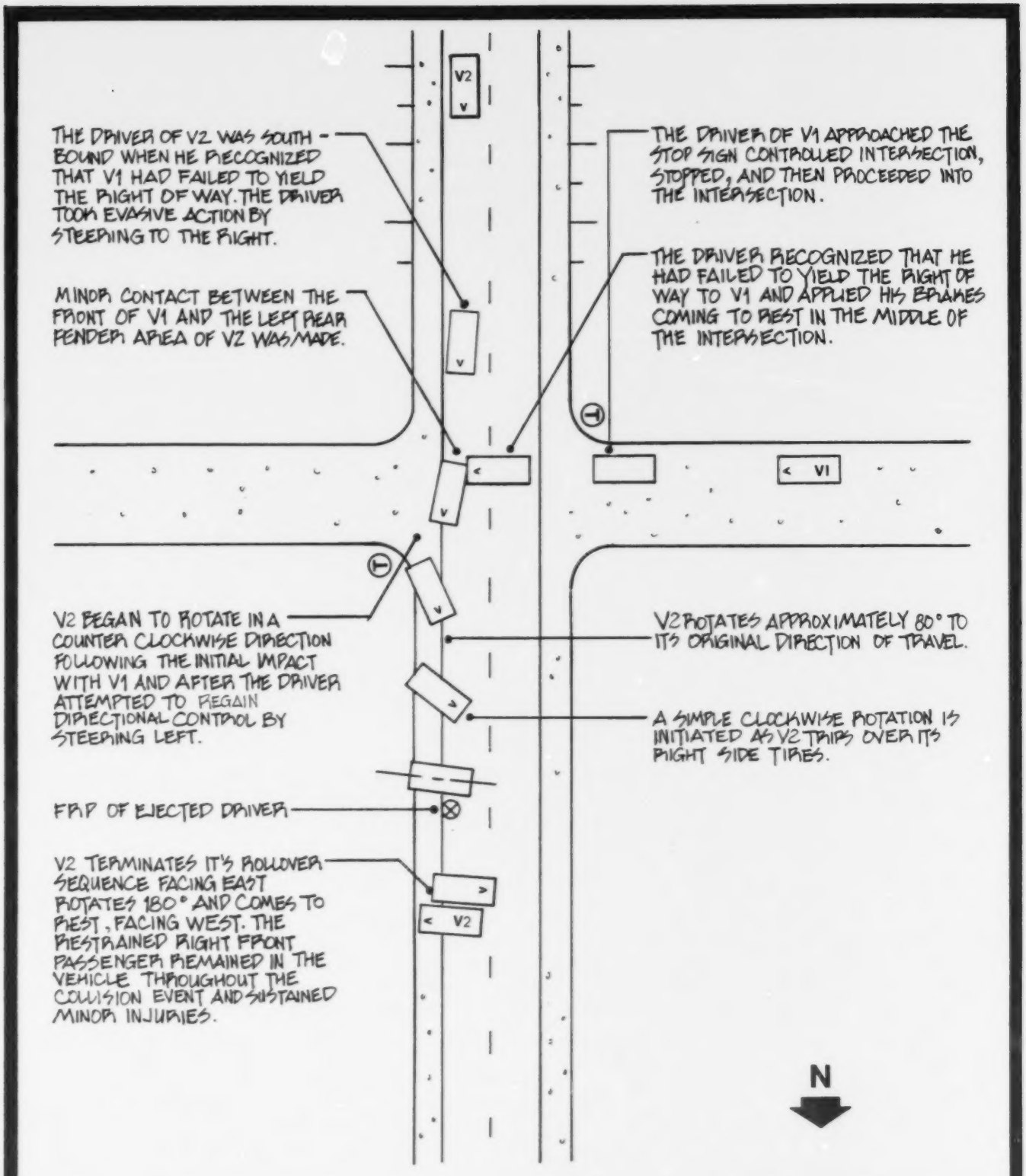
Manitoba Seat Belt Use Evaluation Study

This two vehicle collision occurred at approximately 1100 hours at the intersection of two rural roads. The primary north/south roadway is a provincial asphalt surfaced roadway with gravel shoulders. The secondary east/west roadway is a gravel municipal road. The intersection is controlled by a stop sign for east and westbound traffic. At the time of the incident, visibility was good under clear skies.

V1, a 1967 Ford F-500 grain truck, operated by a 59 year old male, was westbound. There was no occupant restraint device provided for the occupants of this vehicle. V2, a 1982 Toyota pickup, operated by a 57 year old male, was southbound. The driver of V2 was accompanied by a 58 year old female seated in the right front passenger seat. The passenger was utilizing the available two point lap belt, while the driver was not.

The collision was initiated as V1 stopped at the stop sign and then proceeded into the intersection in order to continue west. While in the intersection the driver of V1 recognized that V2 was approaching from his right side and applied his brakes. The driver of V2 attempted to avoid a collision with V1 by steering right onto the gravel shoulder. This steering maneuver was not enough to prevent the right front bumper of V1 from contacting the left rear fender area of V2. Following this minor impact, V2 began to rotate in a counterclockwise direction while travelling along the gravel shoulder. V1 had rotated approximately 80° when it re-entered the travel portion of the roadway and subsequently tripped on its right side tires. During the first revolution of the simple clockwise rollover, V1 violently struck the ground with its left front side and hood area causing the unrestrained driver to load the driver side door and be partially ejected. During the subsequent rollover sequence the driver was completely ejected from his vehicle.

The driver of V1 did not sustain any AIS codeable injuries while the right front passenger seat passenger in V2 remained in the vehicle and sustained minor superficial injuries (MAIS 1). The driver of V2 was eventually completely ejected from his vehicle and sustained critical head (MAIS 4), chest (MAIS 5) and abdominal injuries (MAIS 4). He was pronounced dead at the scene of the collision.


V2
THE DRIVER OF V2 WAS SOUTH - BOUND WHEN HE RECOGNIZED THAT V1 HAD FAILED TO YIELD THE RIGHT OF WAY. THE DRIVER TOOK EVASIVE ACTION BY STEERING TO THE RIGHT.
MINOR CONTACT BETWEEN THE FRONT OF V1 AND THE LEFT REAR FENDER AREA OF V2 WAS MADE.
THE DRIVER OF V1 APPROACHED THE STOP SIGN CONTROLLED INTERSECTION, STOPPED, AND THEN PROCEEDED INTO THE INTERSECTION.
THE DRIVER RECOGNIZED THAT HE HAD FAILED TO YIELD THE RIGHT OF WAY TO V1 AND APPLIED HIS BRAKES COMING TO REST IN THE MIDDLE OF THE INTERSECTION.
V1
V2 BEGAN TO ROTATE IN A COUNTER CLOCKWISE DIRECTION FOLLOWING THE INITIAL IMPACT WITH V1 AND AFTER THE DRIVER ATTEMPTED TO REGAIN DIRECTIONAL CONTROL BY STEERING LEFT.
V2 ROTATES APPROXIMATELY 80° TO ITS ORIGINAL DIRECTION OF TRAVEL.
A SIMPLE CLOCKWISE ROTATION IS INITIATED AS V2 TRIPS OVER ITS RIGHT SIDE TIRES.
FINAL OF EJECTED DRIVER
V2 TERMINATES IT'S ROLLOVER SEQUENCE FACING EAST ROTATES 180° AND COMES TO REST, FACING WEST. THE RESTRAINED RIGHT FRONT PASSENGER REMAINED IN THE VEHICLE THROUGHOUT THE COLLISION EVENT AND SUSTAINED MINOR INJURIES.
V2
N

UOM 607

V1 1967 FORD F-500 GRAIN TRUCK

V2 1982 TOYOTA PICK UP

DIAGRAM NOT TO SCALE.

This two vehicle rollover collision occurred at approximately 1600 hours at the intersection of two rural roadways. The primary, asphalt surfaced, eastbound roadway was in good condition and dry. South of the intersection, the secondary roadway is an asphalt surfaced provincial roadway. North of the intersection the provincial road terminates as the secondary road leads into a farmer's field. There is a relatively unobstructed view between westbound vehicles and northbound vehicles approaching the intersection. Due to a low sun, visibility may have been slightly reduced for westbound traffic. Traffic flow at the intersection is regulated by simple stop signs for the traffic on the secondary road.

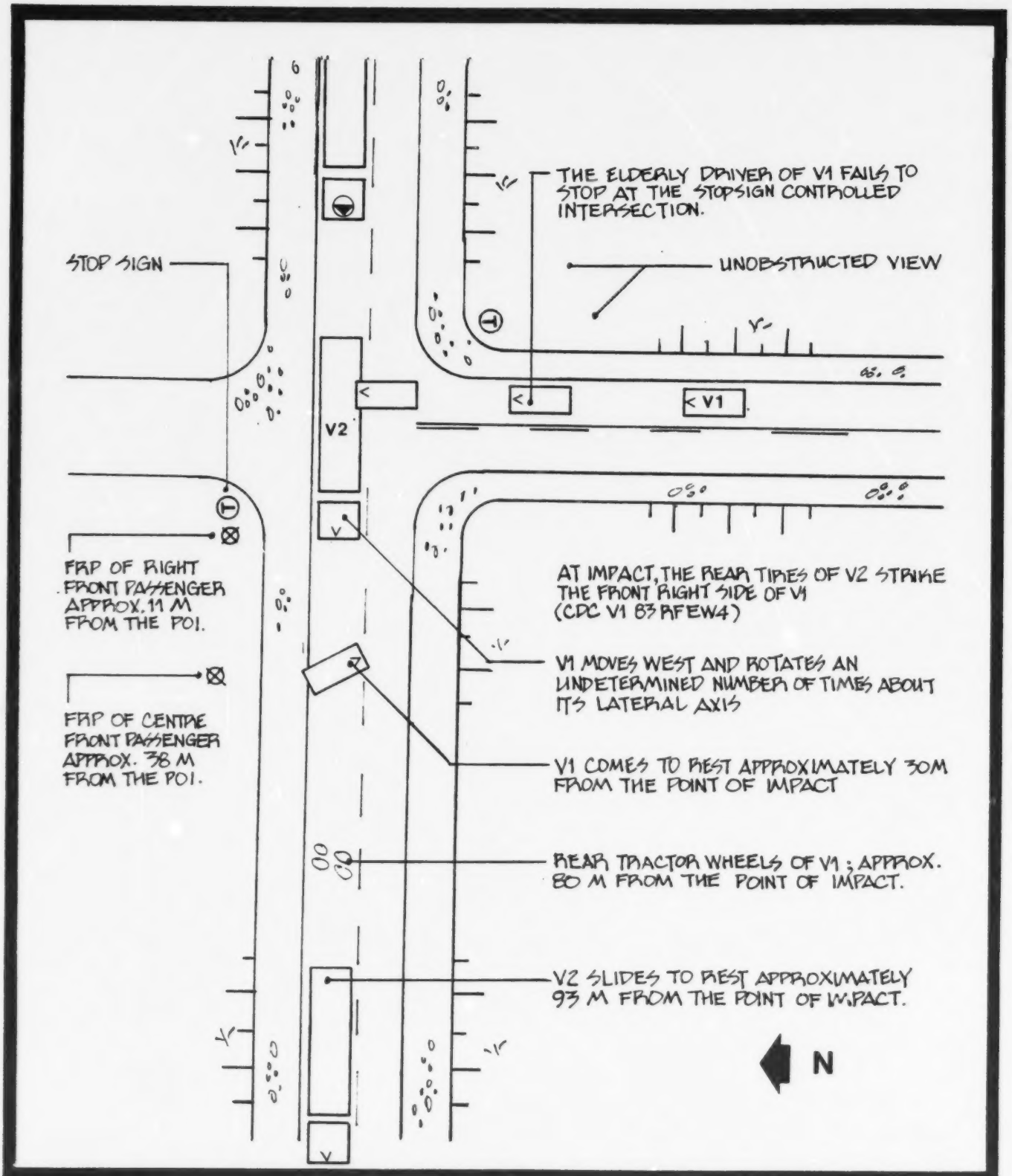
V1, a 1981 GMC pickup, operated by an 81 year old male, was northbound. The driver was accompanied by a 70 year old female seated in the center seating position and a 40 year old male seated in the right front passenger seat. Although the driver was using the available three point lap and torso restraint system, both passengers in V1 were unrestrained. V2, a 1984 Freightliner semitractor trailer unit, operated by a 32 year old male, was westbound.

This collision was initiated as the driver of V1 approached the intersection, failed to stop and yield the right of way to the westbound tractor trailer, and entered the intersection. The front of V1 partially underroad the trailer unit before the rear tires of V2 struck the front right fender area of V1 (CDC V1, 83RFEW4). This caused V1 to move west 90° to its original direction of travel, and begin a violent counterclockwise rotation. V1 came to rest approximately 30 m west of the POI while the rear set of dual wheels (separated from the trailer at impact) came to rest approximately 80 m west of V1. V2 eventually slid to rest approximately 43 m from the POI.

During the crash phase both unrestrained occupants moved right, loading the passenger side door causing it to fail before they were completely ejected.

The right front passenger came to rest in the grassy ditch near the shoulder approximately 12 m west of the POI while the center passenger came to rest approximately 38 m west of the POI, also in the north grassy ditch area. The restrained driver moved right upon impact, loaded his restraint system and remained in the vehicle throughout the crash event.

The driver was pronounced dead approximately 2 hours later, in hospital due to chest (MAIS 4), abdominal (MAIS 2) and extremity (MAIS 3) injuries. It is probable that the driver's ability to tolerate the forces exerted on him during the collision was compromised by his advanced age. Both ejected passengers were pronounced dead at the scene. The male sustained critical head (MAIS 3), facial (MAIS 4), abdominal (MAIS 4) and extremity (MAIS 3) injuries while the female passenger sustained fatal injuries to the head (MAIS 3), chest (MAIS 5), abdomen (MAIS 4) and extremity (MAIS 3).

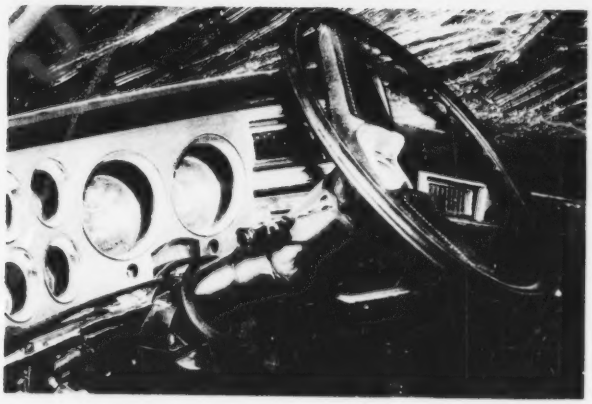

THE ELDERLY DRIVER OF V1 FAILS TO STOP AT THE STOPSIGN CONTROLLED INTERSECTION.
STOP SIGN
UNOBSTRUCTED VIEW
V2
V1
FRP OF RIGHT FRONT PASSENGER APPROX. 11 M FROM THE POI.
FRP OF CENTRE FRONT PASSENGER APPROX. 38 M FROM THE POI.
AT IMPACT, THE REAR TIRES OF V2 STRIKE THE FRONT RIGHT SIDE OF V1 (CDC V1 03 RFEW4)
V1 MOVES WEST AND ROTATES AN UNDETERMINED NUMBER OF TIMES ABOUT ITS LATERAL AXIS
V1 COMES TO REST APPROXIMATELY 30M FROM THE POINT OF IMPACT
REAR TRACTOR WHEELS OF V1 ; APPROX. 80 M FROM THE POINT OF IMPACT.
V2 SLIDES TO REST APPROXIMATELY 93 M FROM THE POINT OF IMPACT.
N

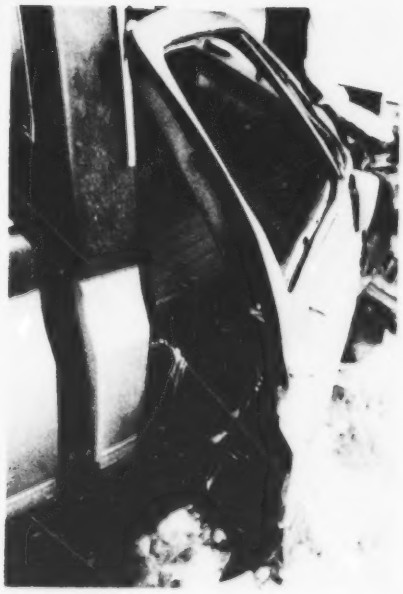
UOM 721

V1 1981 GMC PICK UP

V2 1984 FREIGHT LINER TRACTOR TRAILER

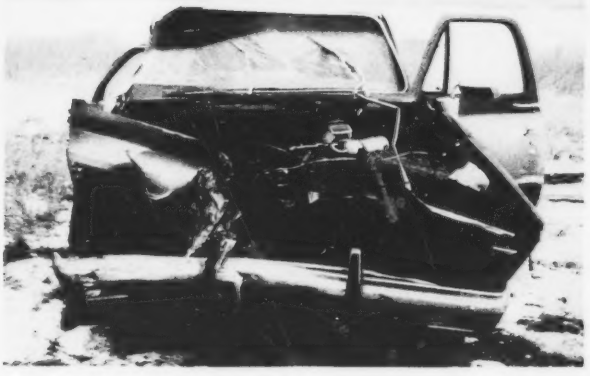
DIAGRAM NOT TO SCALE.





UOM 721

Manitoba Seat Belt Use Evaluation Study



UOM 721 **Manitoba Seat Belt Use Evaluation Study**

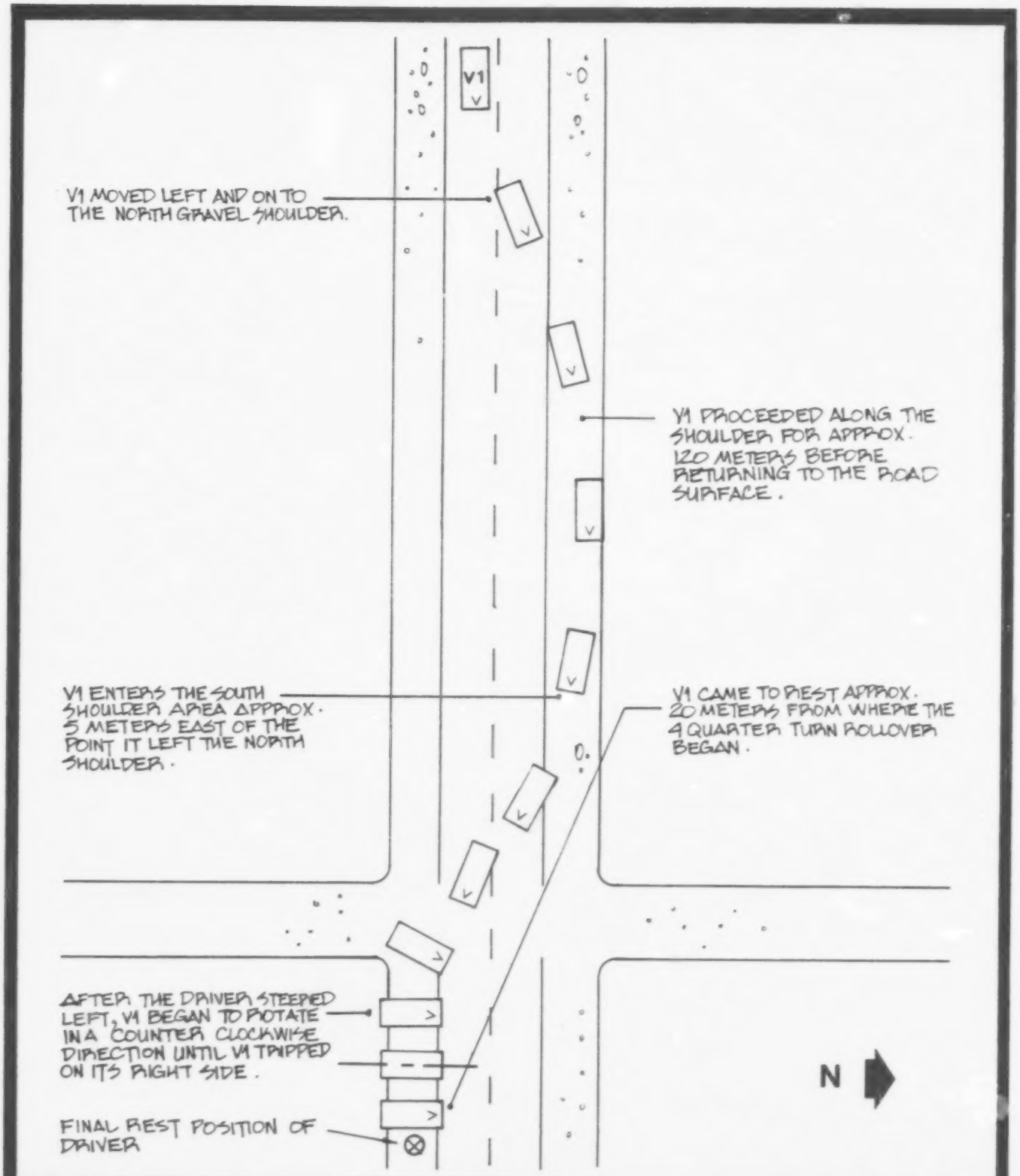
This single vehicle rollover collision occurred at approximately 1500 hours on a two lane, two way, undivided rural roadway. The asphalt road surface was in good condition and dry. A significant pavement edge drop off existed between the road surface and the gravel shoulders. Visibility was unrestricted.

V1, a 1977 Dodge van, operated by a 73 year old female, was eastbound. The driver was accompanied by a 43 year old female seated in the right front passenger seat. Between the two front seats was a cat secured in a box. Both occupants were using the available two point lap belts provided for their seating positions, however, it is highly probable that the obese driver was wearing her lap belt loosely.

This collision event was initiated as the driver attempted to prevent the cat from escaping from the box it was placed in. This action caused the driver to allow her vehicle to move left, cross the westbound traffic lanes and enter the north shoulder area. V1 proceeded along the north shoulder for approximately 40 m when the driver steered right, moved off the shoulder area and crossed the normal travel lanes. It is probable that as the driver entered the south shoulder area (approximately 5 m from where it left the north shoulder) the driver steered left again. This steering input caused V1 to rotate in a counterclockwise direction approximately 90° to its original direction of travel. V1 then tripped on its right side tires initiating a simple four quarter turn clockwise rollover about its longitudinal axis. V1 eventually came to rest upright approximately 20 m from where it tripped.

During the rollover, the driver, restrained by the lap belt, was completely ejected from her vehicle. She sustained critical head (MAIS 4), facial (MAIS 2), chest (MAIS 4) and abdominal (MAIS 4) injuries and was pronounced dead upon arrival at hospital. The restrained right front passenger remained fully in the occupant compartment and was uninjured.

It is probable that the conversion of the van to a camper type vehicle increased the center of gravity of V1 and therefore reduced its stability. This would have increased the likelihood of the vehicle rolling over in cases of lateral deceleration.


V1
V1 MOVED LEFT AND ON TO THE NORTH GRAVEL SHOULDER.
V1 PROCEEDED ALONG THE SHOULDER FOR APPROX. 120 METERS BEFORE RETURNING TO THE ROAD SURFACE.
V1 ENTERS THE SOUTH SHOULDER AREA APPROX. 5 METERS EAST OF THE POINT IT LEFT THE NORTH SHOULDER.
V1 CAME TO REST APPROX. 20 METERS FROM WHERE THE 4 QUARTER TURN ROLLOVER BEGAN.
AFTER THE DRIVER STEERED LEFT, V1 BEGAN TO ROTATE IN A COUNTER CLOCKWISE DIRECTION UNTIL V1 TRIPPED ON ITS RIGHT SIDE.
FINAL REST POSITION OF DRIVER
N

UOM 722 **V1** 1977 DODGE VAN WITH CAMPER CONVERSION

DIAGRAM NOT TO SCALE.

UOM 722 **Manitoba Seat Belt Use Evaluation Study**

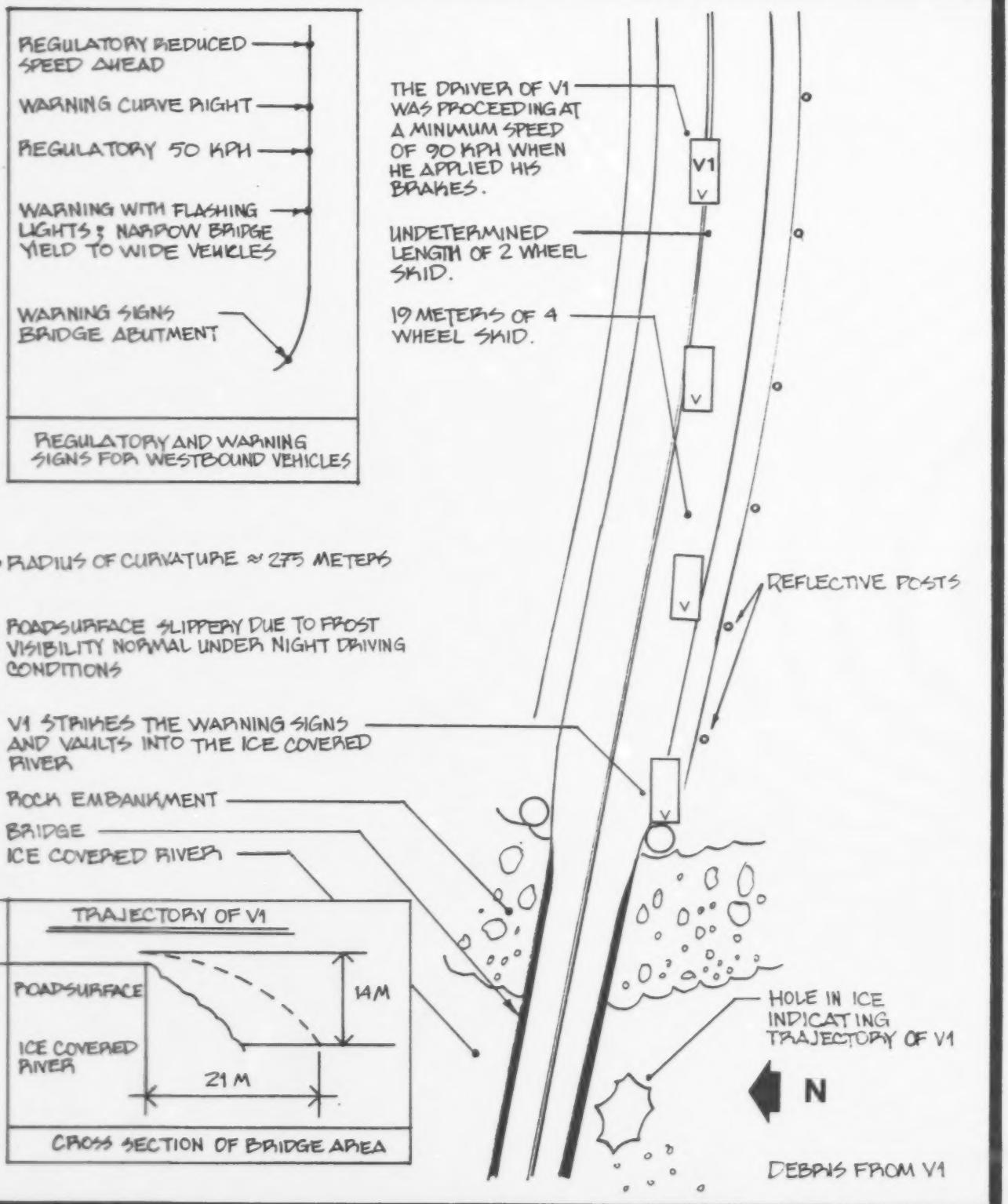
This single vehicle rollover collision occurred at approximately 0400 hours on a two lane, two way, rural roadway. At the scene of the collision the road curves to the right and enters a narrow bridge. The bridge abutment is unprotected without guardrails on either side. The curve is adequately identified by a series of warning signs prior to the curve and reflective posts through the curve's length. At the time of the collision, visibility was normal under night driving conditions while the road surface was slippery due to a layer of frost which had accumulated.

V1, a 1981 Oldsmobile four door passenger car, operated by an alcohol impaired 22 year old male, was westbound. It is probable that the driver and sole occupant of V1 was restrained by his available three point restraint system.

The collision was initiated as the driver, travelling approximately 90 kph, applied his brakes in order to negotiate the curve to the right. V1 skidded more than 20 m before it left the road surface on the left side of the bridge entrance. V1 struck a bridge warning sign and then vaulted approximately 21 m before it struck the ice covered river area.

Prior to the vehicle's removal, the deceased was observed to be located in the rear of his vehicle. The power door locks and power windows were not operational.

The driver did not sustain any AIS codeable injuries as the cause of death was determined to be due to drowning.


REGULATORY REDUCED SPEED AHEAD
WARNING CURVE RIGHT
REGULATORY 50 KPH
WARNING WITH FLASHING LIGHTS; NARROW BRIDGE YIELD TO WIDE VEHICLES
WARNING SIGNS BRIDGE ABUTMENT
REGULATORY AND WARNING SIGNS FOR WESTBOUND VEHICLES
THE DRIVER OF V1 WAS PROCEEDING AT A MINIMUM SPEED OF 90 KPH WHEN HE APPLIED HIS BRAKES.
UNDETERMINED LENGTH OF 2 WHEEL SKID.
19 METERS OF 4 WHEEL SKID.
V1
REFLECTIVE POSTS
• RADIUS OF CURVATURE ≈ 275 METERS
• ROADSURFACE SLIPPERY DUE TO FROST
• VISIBILITY NORMAL UNDER NIGHT DRIVING CONDITIONS
V1 STRIKES THE WARNING SIGNS AND VAULTS INTO THE ICE COVERED RIVER
ROCK EMBANKMENT
BRIDGE
ICE COVERED RIVER
TRAJECTORY OF V1
ROADSURFACE
ICE COVERED RIVER
14 M
21 M
CROSS SECTION OF BRIDGE AREA
HOLE IN ICE INDICATING TRAJECTORY OF V1
N
DEBRIS FROM V1

UOM 742
PCS 089

V1 1981 OLDSMOBILE 4 DOOR PASSENGER CAR

DIAGRAM NOT TO SCALE.

PCS 089
UOM 742

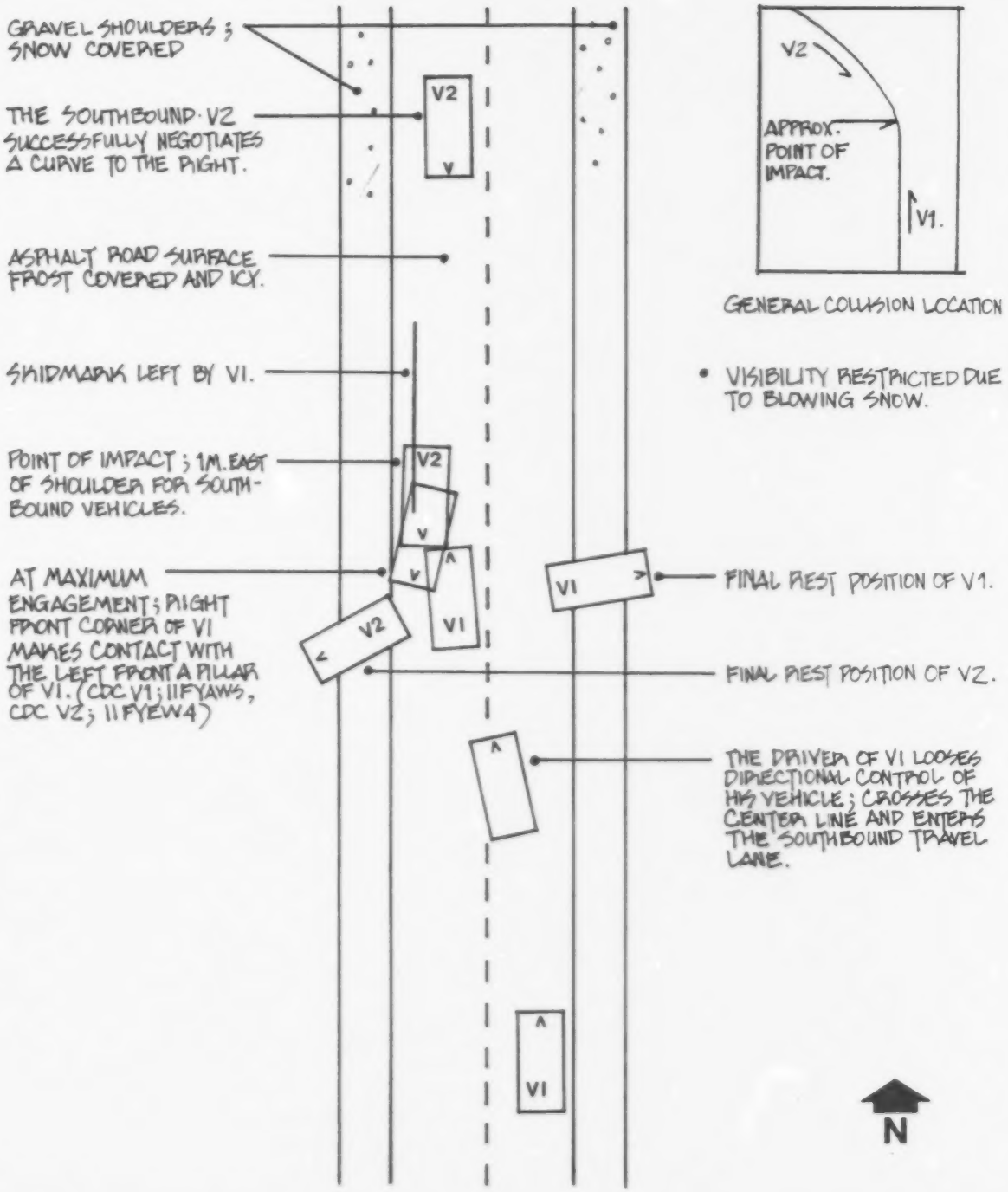
Manitoba Seat Belt Use Evaluation Study

This two vehicle head-on collision occurred at approximately 0800 hours on a two lane, two way, undivided, rural highway. At the time of the collision the concrete road surface was frost covered and slippery. Visibility was reduced under overcast skies and blowing snow. The general collision location is at the beginning of a curve requiring northbound vehicles to move left.

V1, a 1984 Chevrolet five door passenger car, operated by a 19 year old male, was northbound. The driver and sole occupant of V1 was utilizing his three point lap and shoulder restraint system. V2, a 1981 GMC van, operated by a 61 year old male, was southbound. The driver was accompanied by a 60 year old female seated in the right front passenger seat. Both occupants of V2 were using their available restraint system.

This collision was initiated as the driver of V1 lost directional control of his vehicle under adverse driving conditions, crossed the centerline and entered the southbound travel lane. The driver of V2 braked immediately prior to impact and steered right before striking the left front of V1 (CDC V1, 11FYAW5; CDC V2, 11FYEW4). Following the collision, V1 rotated approximately 90° in a clockwise direction and came to rest on the east shoulder adjacent to the POI. V2 rotated approximately 45° in a clockwise direction before coming to rest on the west shoulder within 2 m of the POI.

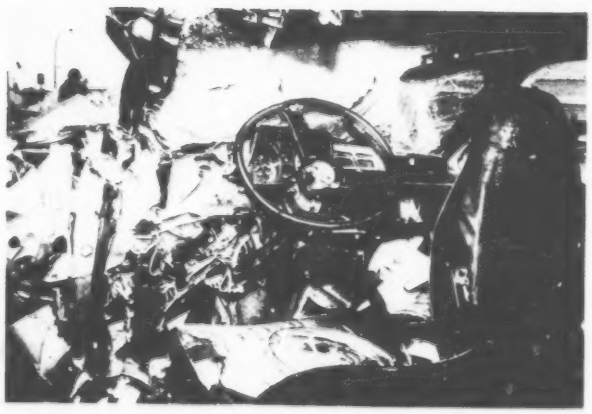
During the crash phase the restrained driver of V1 moved forward and slightly to the left, loading the intruding steering column, the lower dash area and his restraint system. The driver's head also contacted the left "A" pillar and the intruding hood of V2. The driver sustained severe head (MAIS 5), facial (MAIS 3), chest (MAIS 4), abdomen (MAIS 5) and extremity (MAIS 3) injuries and was pronounced dead at the scene. The restrained occupants of V2 sustained undetermined minor injuries.


GRAVEL SHOULDERS; SNOW COVERED
THE SOUTHBOUND V2 SUCCESSFULLY NEGOTIATES A CURVE TO THE RIGHT.
ASPHALT ROAD SURFACE FROST COVERED AND ICY.
SKIDMARK LEFT BY V1.
POINT OF IMPACT; 1M. EAST OF SHOULDER FOR SOUTHBOUND VEHICLES.
AT MAXIMUM ENGAGEMENT; RIGHT FRONT CORNER OF V1 MAKES CONTACT WITH THE LEFT FRONT A PILLAR OF V1. (CDC V1; 11FYAW5, CDC V2; 11FYEW4)
V2
V1
V2
APPROX. POINT OF IMPACT.
V1.
GENERAL COLLISION LOCATION
• VISIBILITY RESTRICTED DUE TO BLOWING SNOW.
FINAL REST POSITION OF V1.
FINAL REST POSITION OF V2.
THE DRIVER OF V1 LOOSES DIRECTIONAL CONTROL OF HIS VEHICLE; CROSSES THE CENTER LINE AND ENTERS THE SOUTHBOUND TRAVEL LANE.
N

UOM 766
PCS 100

V1 1984 CHEVROLET FIVEDOOR PASS CAR.
V2 1981 CHEVROLET VAN

DIAGRAM NOT TO SCALE.



PCS 100
UOM 766

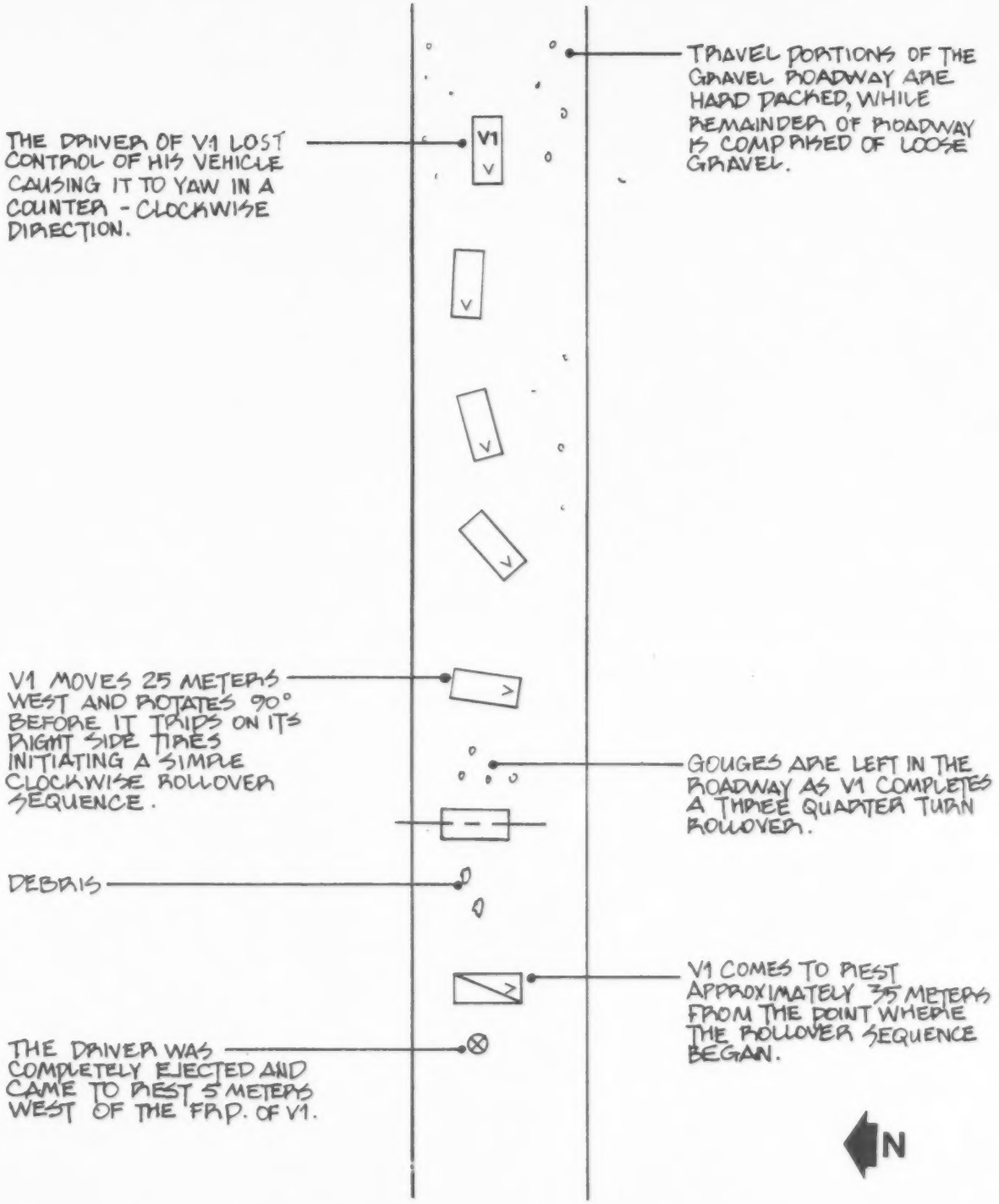
Manitoba Seat Belt Use Evaluation Study

This single vehicle rollover collision occurred at approximately 1900 hours on a two lane, rural roadway. The roadway was straight and level and orientated in an east/west direction. The worn gravel surface was hard along the travel lanes, however, the remainder of the road surface was comprised of loose gravel. At the time of the collision event, the surface was dry; the ambient weather conditions were clear and dry.

V1, a 1979 Austin Mini, operated by a 20 year old male, was westbound. The owner of the vehicle, a 27 year old female, occupied the right front passenger seat. Although the passenger was restrained by the available seat belt, the driver was unrestrained.

While travelling at an estimated speed of between 75 and 85 kph the driver lost directional control of his vehicle. It is probable that after moving to the right, the driver overcorrected while attempting to regain directional control. This caused the vehicle to yaw in a counterclockwise direction until the vehicle rotated approximately 90° from its original direction of travel. At this point the vehicle tripped on its right side wheels initiating a simple three quarter turn rollover about it's longitudinal axis. The vehicle came to rest approximately 35 m from the point where the driver originally lost directional control and began to yaw.

During the rollover the unrestrained driver was completely ejected out of the left front window and was crushed between the ground and the roof of his vehicle. The driver came to rest approximately 5 m west of the final rest position of V1. He sustained critical head (MAIS 5) and chest (MAIS 5) injuries and was pronounced dead at the scene. The restrained front seat passenger remained in the vehicle and sustained only minor chest (MAIS 1) injuries. She was transported to hospital, treated and then released.


TRAVEL PORTIONS OF THE GRAVEL ROADWAY ARE HARD PACKED, WHILE REMAINDER OF ROADWAY IS COMPRISED OF LOOSE GRAVEL.
THE DRIVER OF V1 LOST CONTROL OF HIS VEHICLE CAUSING IT TO YAW IN A COUNTER - CLOCKWISE DIRECTION.
V1
V1 MOVES 25 METERS WEST AND ROTATES 90° BEFORE IT TRIPS ON ITS RIGHT SIDE TIRES INITIATING A SIMPLE CLOCKWISE ROLLOVER SEQUENCE.
GOUGES ARE LEFT IN THE ROADWAY AS V1 COMPLETES A THREE QUARTER TURN ROLLOVER.
DEBRIS
V1 COMES TO REST APPROXIMATELY 35 METERS FROM THE POINT WHERE THE ROLLOVER SEQUENCE BEGAN.
THE DRIVER WAS COMPLETELY EJECTED AND CAME TO REST 5 METERS WEST OF THE FRP. OF V1.
N

UOM 879
PCS 150

V1 1979 AUSTIN TWO DOOR PASSENGER CAR.

DIAGRAM NOT TO SCALE.

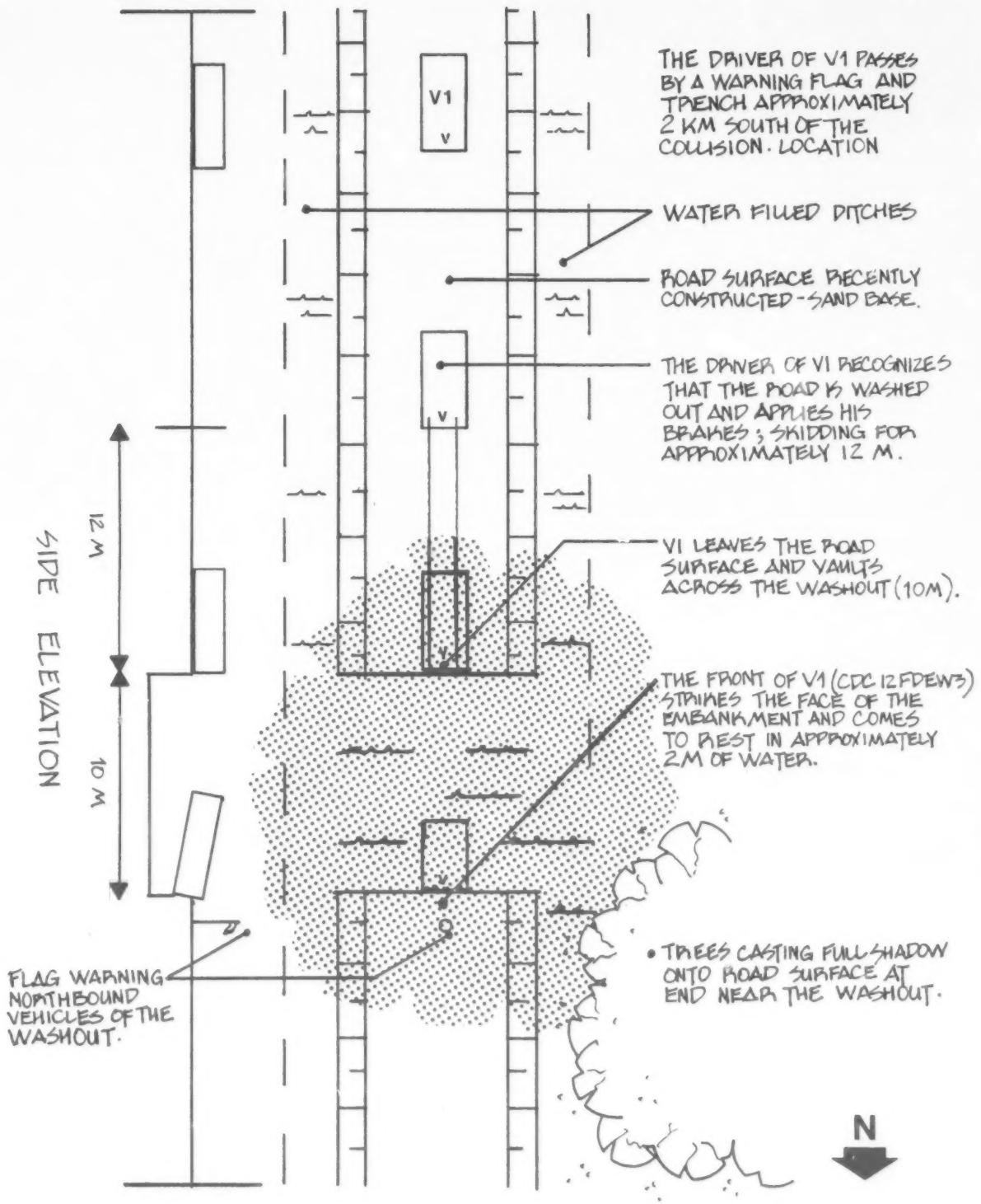
PCS 150
UOM 879

Manitoba Seat Belt Use Evaluation Study

This single vehicle collision occurred at approximately 0800 hours on a two way, two lane, municipal road. The road surface, consisting of sand and other fines, was recently re-constructed and fairly hard packed at the time of the collision. During the two days prior to this incident heavy rains had fallen in the area causing widespread flooding of ditches and farmlands. This resulted in the "washout" of numerous roads throughout the area. The roadway involved in this incident was completely severed at the collision location. The washout, approximately 10 m in width, joined the water filled ditches on either side of the road.

V1, a 1983 Plymouth, was northbound operated by a 24 year old unrestrained male. The driver was proceeding at approximately 80 kph when he recognized that the road terminated due to the washout, and applied the brakes. V1 left approximately 12 m of skid marks before leaving the road surface and vaulting across the washout. V1 travelled approximately 10 m before it struck the vertical embankment defining the washout (CDC, 12FDEW3).

At impact, the driver moved violently forward into the non-energy absorbing steering column and dash area. The driver was alert and conscious immediately following the impact but died 3 hours later of critical chest injuries (MAIS 5).


V1
THE DRIVER OF V1 PASSES BY A WARNING FLAG AND TRENCH APPROXIMATELY 2 KM SOUTH OF THE COLLISION. LOCATION
WATER FILLED DITCHES
ROAD SURFACE RECENTLY CONSTRUCTED - SAND BASE.
THE DRIVER OF V1 RECOGNIZES THAT THE ROAD IS WASHED OUT AND APPLIES HIS BRAKES; SKIDDING FOR APPROXIMATELY 12 M.
V1 LEAVES THE ROAD SURFACE AND VAULTS ACROSS THE WASHOUT (10M).
THE FRONT OF V1 (CDC 12FDEW3) STRIKES THE FACE OF THE EMBANKMENT AND COMES TO REST IN APPROXIMATELY 2M OF WATER.
TREES CASTING FULL SHADOW ONTO ROAD SURFACE AT END NEAR THE WASHOUT.
FLAG WARNING NORTHBOUND VEHICLES OF THE WASHOUT.
12 M
10 M
SIDE ELEVATION
N

UOM 905
PCS 155

V1 1963 PLYMOUTH 4 DOOR PASSENGER CAR

DIAGRAM NOT TO SCALE.

PCS 155
UOM 905

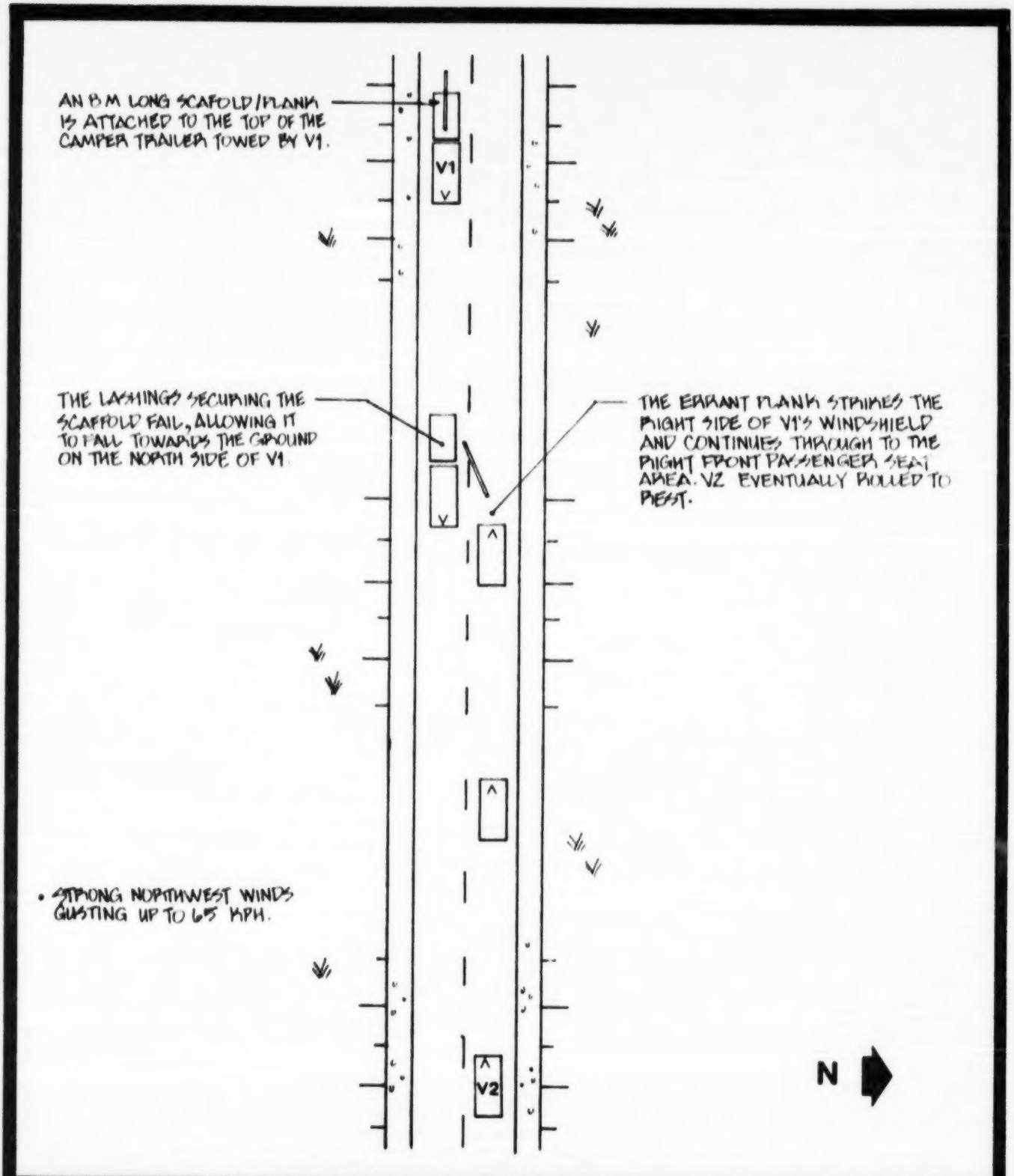
Manitoba Seat Belt Use Evaluation Study

This two vehicle collision occurred at approximately 1200 hours on a two lane, rural highway. The roadway is comprised of an asphalt road surface and gravel shoulders.

V1, a 1974 Ford pickup, was westbound towing a full size camper trailer. The male driver was accompanied by his 39 year old male passenger in the right front passenger seat. On top of the trailer, a 24 foot long catwalk (12" x 6") was secured using rubber lashings attached to spikes at the front and back of the trailer roof. V2, a 1984 Plymouth, operated by a 79 year old male, was eastbound. The driver was accompanied by an 84 year old female in the right front passenger seat. It is highly probable tha both occupants were unrestrained at the time of the incident.

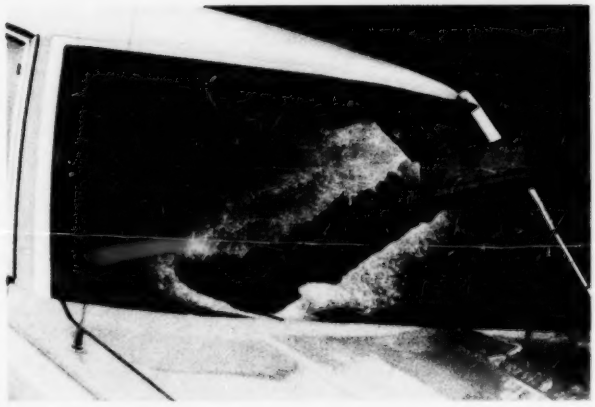
The incident occurred as the lashings securing the catwalk to V1's trailer failed just as V2 approached V1. As the lashings failed, the scaffolding fell directly from the trailer onto V1 penetrating through the front windshield. At impact, one end of the scaffold broke off while the other end remained inside the occupant compartment pinning the right front passenger in the seat. V2 eventually came to rest on the roadway an unknown distance from the POI. It is possible that the lashings failed due to the strong winds at the time of the collision.

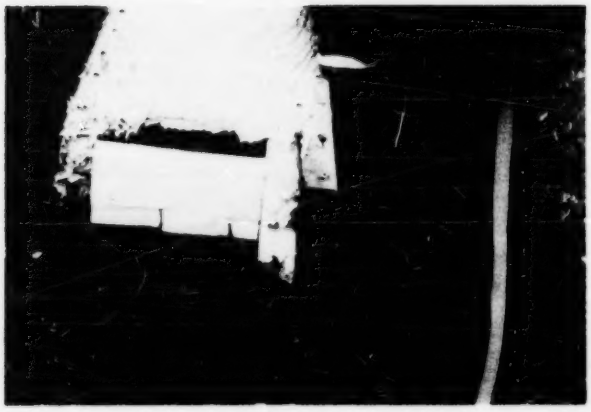
Both occupants were pronounced dead at the scene. The driver sustained severe head (MAIS 4) and face (MAIS 2) injuries while the front seat occupant sustained critical chest (MAIS 6) and head (MAIS 4) injuries.


AN 8 M LONG SCAFOLD/PLANK IS ATTACHED TO THE TOP OF THE CAMPER TRAILER TOWED BY V1.
V1
THE LASHINGS SECURING THE SCAFFOLD FAIL, ALLOWING IT TO FALL TOWARDS THE GROUND ON THE NORTH SIDE OF V1.
THE ERRANT PLANK STRIKES THE RIGHT SIDE OF V1'S WINDSHIELD AND CONTINUES THROUGH TO THE RIGHT FRONT PASSENGER SEAT AREA. V2 EVENTUALLY ROLLED TO REST.
• STRONG NORTHWEST WINDS GUSTING UP TO 65 KPH.
V2
N

UOM 945
PCS 176
DIAGRAM NOT TO SCALE.

V1 1974 FORD PICKUP TOWING A CAMPER TRAILER
V2 1985 PLYMOUTH FOUR DOOR PASSENGER CAR





PCS 176
UOM 945

Manitoba Seat Belt Use Evaluation Study

APPENDIX G

MOTORCYCLE COLLISION SAMPLE PLAN

Selected Locations & Police Force	1984				1985			
	Sample Interval		Random Start		Sample Interval		Random Start	
	Fatal	Nonfatal	Rep 1	Rep 2	Fatal	Nonfatal	Rep 1	Rep 2
Winnipeg City	1	1 in 10	4	3	1	1 in 7	9	3
Brandon City	1	1 in 10	9	5	1	1 in 7	9	5
Winnipeg Sub	1	1 in 10	8	4	1	1 in 7	8	4
Brandon Sub	1	1 in 10	2	6	1	1 in 7	2	6

APPENDIX H

COLLISION AND INJURY CHARACTERISTICS; MOTORCYCLE FATALTIES

Case No.	Age	Sex	Engine Size	Alcohol Involved	Helmet Used	Helmet Retained	Maximum Severity of Injury (AIS ≥ 2) Head	Face	Chest	Abdom	Extrem	Primary Injuries Contributing to Death
583	20	M	900	Yes	Yes	Yes			6			Transection of thoracic aorta
583	24	M	900	Yes	Yes	Yes	2	2	6	2	2	Transection of thoracic aorta
587	26	M	200	Yes	No	N/A	6					Ring-type skull fracture/laceration medulla and cerebellum
590	22	M	1100	Yes	No	N/A	5					Fracture skull/brain injury
602	21	F	175	No	Yes	No	6		3	4	3	Fracture dislocation atlanto-occipital cervical spine
611	18	M	750	Yes	No	N/A	5	3	5	5	3	Massive skull fracture; maceration of brain; ruptured liver and distal aorta
640	11	M	80	No	Yes	Yes	4					Transverse basal skull fracture/brain injuries
640	12	M	80	No	Yes	Yes	4		3	4		Multiple brain lacerations; neck fracture at C2
649	19	M	400	No	Yes	Yes	3		4	4	3	Pulmonary contusions; head injuries; lacerated liver
652	23	M	950	No	Yes	Yes	5		5	5		Dislocation atlanto-occipital joint and transection medullo pontine junction; lacerated aorta
696	18	M	1000	No	Yes	Yes			5	5	2	Fracture lumbar and thoracic vertebrae; fracture ribs with lung lacerations; and lacerated liver
799	32	M	360	Yes	Yes	Yes	3				3	Death due to drowning
821	19	M	550	Yes	Yes	Yes	3	2	5	5		Ruptured and macerated liver; ruptured kidney; fracture ribs with lung lacerations; ruptured myocardium; basal skull fx with cerebral contusions
823	21	M	Moped	Yes	No	N/A	6		6		3	Transected aorta; fracture/dislocation of cervical spine
832	18	M	750	No	Yes	Yes	4		4			Skull fracture with brain injuries; pulmonary contusions
832	23	M	750	No	Yes	Yes	6		5			Massive basal skull fracture with cerebral hemorrhage; ruptured bronchus
844	22	M	900	Yes	?	Yes			4	5	2	Ruptured bronchus; fracture ribs with flail chest
878	21	M	750	No	Yes	Yes			3	4		Ruptured spleen
880	21	M	500	Yes	Yes*	No	5					Basal skull fracture with cerebral edema
883	23	M	1100	No	Yes	No	5	2	5		3	Multiple chest injuries with ruptured aorta; fracture of atlanto-axial cervical spine with laceration of spinal cord
889	34	M	750	No	Unk	N/A	5	3	5	5	2	Fracture skull with cerebral destruction and severing of spinal cord; extensive lung, heart and liver lacerations
893	22	F	750	Yes	Yes	Yes	5	3				Fracture of base of skull due to facial impact; cerebral trauma
894	17	M	650	Yes	No	N/A	5	3	5			Fracture ribs with lacerated and punctured heart and lung; fracture dislocation of lower cervical spine
910	45	M	1200	No	Yes	Yes			4	5	3	Lacerated spleen; traumatic abdominal evisceraton
910	41	F	1200	No	Yes	Yes	6	3		4	3	Fracture of cervical spine (C1-C7) with complete transection of spinal cord (at formen magnum); laceration spleen
920	12	M	80	No	No	N/A	4				3	Cerebral lacerations & contusions
920	13	M	80	No	No	N/A	3		4	5	3	Cerebral contusions; avulsed kidney; lacerated liver
931	21	M	900	Yes	No	N/A	3	2	4		3	Pelvic fracture with massive blood loss; focal cerebral contusions
974	36	M	400	No	Yes	Yes				5		Lacerated liver (death occurred 26 days post-crash due to hepatic failure)

*Not Approved Helmet